
PEST MANAGEMENT EVALUATION For Strawberries in California

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**Multi-Disciplinary Approach To Methyl Bromide Replacements
In Strawberries**

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ABSTRACT

California produces more than 80% of the fresh market and processed strawberries grown in the United States and about 20% of the world's production. This productivity is accomplished through an extensive pest management program using a wide variety of cultural practices in conjunction with biological and chemical control techniques. California's strawberry industry has a relatively small number of chemical tools available to them. Methyl bromide, the chemical tool used to manage the largest number of significant pests and diseases, is being phased out and will no longer be available to the industry in 2006. Soil fumigation with methyl bromide has played a central role in pest management and productivity in almost all California strawberry production, with the exception of organically-grown fields. With the impending loss of this tool, the strawberry industry is developing alternative methods for control of the primary strawberry pests. This Pest Management Evaluation describes the cultural, biological, and chemical pest management tools that are currently used by California's strawberry industry to control specific pests, as well as new cultural, biological and chemical tools being developed that may become important components of the strawberry pest management program in the future.

PEST MANAGEMENT EVALUATION: MULTI-DISCIPLINARY APPROACH TO METHYL BROMIDE REPLACEMENT IN STRAWBERRIES

March 9, 2000

EXECUTIVE SUMMARY

Strawberry production in California is intensive and highly productive, with productivity per acre being over 4 times higher than that of most other states. This productivity is accomplished, in part, through an extensive pest management program using a wide variety of cultural practices in conjunction with biological and chemical control techniques. California's strawberry industry has a relatively small number of chemical tools available to them and, by 2006, the chemical used to manage the largest number of significant pests and diseases, methyl bromide, will no longer be available. The use of methyl bromide will be phased out with a 50% reduction in use mandated in 2001 and a 70% reduction in use in 2003, therefore, 2002 will be the last year that methyl bromide will be available to most growers. As a result, it is crucial to maintain as many of the existing pest management tools as possible to limit future losses in California's production and to maintain strong resistance management programs.

Integrated Pest Management. Strawberry production in California uses an integrated approach to pest management. In an effort to maximize the appropriate control of economically important pests, California growers recognize that a cost-effective program must ensure that pest management tools are not lost due to the onset of resistance. Pest levels are monitored closely to ensure that pest management decisions are initiated prudently and carefully coordinated. As a result, all growers use a mixture of cultural, biological, and chemical control practices to control economically important pests. This Crop Profile describes these practices.

Crucial Role of Fumigation. Soil fumigation prior to planting plays a central role in pest management and productivity for California's strawberry industry. In particular, one single pest management tool, methyl bromide combined with chloropicrin, is used extensively by California's strawberry industry to control a wide variety of soil-borne pests and diseases. With the exception of organically-grown fields, methyl bromide is essentially used on all California strawberry fruit production acreage and all nursery plant production, including nursery stock destined for organic acreage. This combination pre-plant fumigation has proven efficacious against disease agents such

as soil-borne fungi that cause verticillium wilt, Phytophthora root and crown rots, anthracnose, black root rot, charcoal rot, and, significantly, other soil-borne pathogens of unknown etiology that impact strawberry plant yield and quality. Methyl bromide/chloropicrin treatments are also effective for arthropods (such as root weevils, cutworms, strawberry rootworm, white grubs, and garden symphylan and mealybugs), nematodes (such as foliar nematodes), and weed seeds of all species (with a few exceptions). The loss of methyl bromide, as discussed below, will have a significant impact on the productivity and most of the state's current pest management practices.

Important Pests. For strawberries in California, the most important "insect" pests are twospotted spider mites, lygus bugs, cyclamen mites, western flower thrips, aphids, root weevils, and whiteflies. Nematodes are also important though, currently, they are controlled effectively through fumigation. Important diseases include botrytis rot, verticillium wilt, phytophthora crown and root rot, rhizopus fruit rot, mucor fruit rot, powdery mildew, common leaf spot, anthracnose, and other soil-borne pathogens of unknown etiology that reduce strawberry plant vigor, yield and berry quality. Botrytis, verticillium wilt and phytophthora have a significant impact statewide. Chemical tools are needed for infestations or disease outbreaks of these pests. Chemical controls should be maintained for control of the primary pests of strawberries.

Table 1: Chemical Controls of Primary Strawberry Pests	
Chemical	Primary Pests Controlled: Insects & Mites
Avermectin	Twospotted spider mite, Cyclamen mite, Whiteflies
Bacillus thuringiensis	Cutworms, Beet Armyworm
Bifenthrin	Twospotted spider mite, Lygus bugs, Root Weevils
Carbaryl	Cyclamen mite, Cutworms
Carbofuran	Root Weevils
Chloropicrin	Cutworms
Chlorpyrifos	Root Weevils, Cutworms
Diazinon	Lygus bugs, Cyclamen mite, Aphids, Root Weevils
Dicofol	Twospotted spider mite, Cyclamen mite
Endosulfan	Cyclamen mite
Fenbutatin-oxide	Twospotted spider mite
Hexythiazox	Twospotted spider mite
Imidacloprid	Whiteflies
Insecticidal Soap	Lygus bugs, Aphids, Whiteflies
Malathion	Lygus bugs, Aphids

Methomyl	Lygus bugs, Root Weevils, Western Flower Thrips, Cutworms, Beet Armyworm
Methyl Bromide/ Chloropicrin	Root Weevils,
Naled	Lygus bugs, Aphids, Western Flower Thrips
Narrow Range Oil	Twospotted spider mite
Pyrethrin & Piperonyl Butoxide	Western Flower Thrips
Pyrethroids	Beet Armyworm, Whiteflies
Rotenone	Twospotted spider mite
Chemical	Primary Pests Controlled: Nematodes
Chloropicrin	Foliar Nematode, Northern Root Knot Nematode
Metam Sodium	Foliar Nematode, Northern Root Knot Nematode
Methyl Bromide	Foliar Nematode, Northern Root Knot Nematode
Oxamyl	Foliar Nematode, Northern Root Knot Nematode
Chemical	Primary Pests Controlled: Diseases
<i>Ampelomyces quisqualis</i>	Powdery Mildew
Benomyl	Botrytis Fruit Rot, Powdery Mildew, Common Leaf Spot, Anthracnose
Captan	Botrytis Fruit Rot, Rhizopus Fruit Rot, Common Leaf Spot, Anthracnose
Chloropicrin	Verticillium Wilt
Chlorothalonil	Common Leaf Spot
Chitosan	Botrytis Fruit Rot
Copper Hydroxide	Common Leaf Spot
Fenhexamid	Botrytis Fruit Rot
Fosetyl-Aluminum	Phytophthora Crown Rot, Phytophthora Root Rot
Insecticidal Soap	Powdery Mildew
Iprodione	Botrytis Fruit Rot
Mefenoxan	Phytophthora Crown Rot, Phytophthora Root Rot
Metam Sodium	Verticillium Wilt
Methyl Bromide/ Chloropicrin	Verticillium Wilt, Phytophthora Crown Rot, Phytophthora Root Rot, Common Leaf Spot
Micronized Sulfur	Powdery Mildew
Myclobutanil	Powdery Mildew, Common Leaf Spot, Anthracnose
Narrow Range Oil	Powdery Mildew
Potassium Bicarbonate	Powdery Mildew, Common Leaf Spot

Bicarbonate	
Thiophanate-methyl	Botrytis Fruit Rot
Thiram	Botrytis Fruit Rot, Rhizopus Fruit Rot
Chemical	Primary Pests Controlled: Weeds
Chlorthal-Dimethyl	<u>Perennial</u> : Bermudagrass seedling <u>Annual Broadleaf</u> : Burning Nettle, Common Chickweed, Filaree, Lambsquarter, Pigweed, Purslane, Sowthistle <u>Annual Grass</u> : Annual Bluegrass, Barnyardgrass, Italian Ryegrass, Wild Barleys
Metam Sodium	<u>Perennial</u> : Bermuda seedlings, <u>Annual Broadleaf</u> : Burning Nettle, Common Chickweed, Common Groundsel, Filaree, Lambsquarters, Pigweeds, Pineappleweed, Purslane, Sowthistle <u>Annual Grasses</u> : Annual Bluegrass, Barnyardgrass, Italian Ryegrass, Volunteer Grains, Wild Barleys
Methyl Bromide/ Chloropicrin	<u>Perennial</u> : Yellow Nutsedge <u>Annual Broadleaf</u> : Burning Nettle, Common Chickweed, Common Groundsel, Lambsquarters, Pigweeds, Pineappleweed, Purslane, Sowthistle <u>Annual Grasses</u> : Annual Bluegrass, Barnyardgrass, Italian Ryegrass, Volunteer Grains, Wild Barleys
Napropamide	<u>Perennial</u> : Bermudagrass seedling <u>Annual Broadleaf</u> : Common Chickweed, Common Groundsel, Filaree, Lambsquarter, Little Mallow, Pigweeds, Purslane, Sowthistle <u>Annual Grasses</u> : Annual Bluegrass, Barnyardgrass, Italian Ryegrass, Volunteer Grains, Wild Barleys
Paraquat Dichloride	<u>Perennial</u> : Field Bindweed seedlings <u>Annual Broadleaf</u> : Burning Nettle, California Burclover, Common Groundsel, Pigweeds, Pineappleweed, Puncturevine, Purslane, Sowthistle <u>Annual Grasses</u> : Annual Bluegrass, Barnyardgrass, Italian Ryegrass, Volunteer Grains, Wild Barleys
Sethoxydim	<u>Perennial</u> : Bermudagrass seedlings <u>Annual Grasses</u> : Barnyardgrass, Italian Ryegrass, Volunteer Grains, Wild Barleys

Level of Reliance on Chemical Treatments. Most chemicals are applied to less than 10% of the state's strawberry acreage (4). However, fumigant use, currently methyl bromide combined with chloropicrin, is practiced on all but the organically grown production acreage. Fungicide use is also relatively high for some compounds with sulfur, captan, myclobutanil (RALLY), and thiram being used on more than half the acreage (4). Herbicides are not as widely used due to the effectiveness of

methyl bromide as a preemergent herbicide and the common use of plastic mulch on California fields.

Vulnerable Chemicals Under FQPA. The California strawberry industry is not solely dependent on any chemical that is currently thought to be vulnerable under FQPA. However, relatively few chemical ingredients are registered for use on strawberries, a minor crop. As a result, the loss of any single fungicide will adversely impact the IPM practices used by growers and accelerate the onset of resistance. Similarly, loss of any of the insecticides available to the industry would have a significant adverse effect on resistance management and the use of beneficial organisms. The continued ability to have these pest management tools available so that they may be used for control of periodic or sporadic outbreaks could be crucial to the industry. NAPIAP (USDA) has produced a thorough evaluation of the potential impacts of the loss of individual pesticides on the industry (7). This document concludes that the loss of any of several existing pesticides would result in significant adverse impacts on California's strawberry industry.

Use of Chemical Alternates. Use of new, reduced risk pesticides such as azadirachtin (NEEM OIL) and *Bacillus thuringiensis* (Bt) are still relatively limited (less than 0.1% and less than 9%, respectively) but the use of these biochemical pesticides is increasing. Several new reduced-risk pesticides such as the fungicides fenhexamid (ELEVATE) and chitosan (ELEXA) are becoming available and will be integrated into the relatively small family of pest management tools available to strawberry growers in the future.

New Active Ingredients Needed. With the impending losses of methyl bromide and other chemicals such as iprodione and vinclozolin that play important roles in California strawberry production, the industry needs new pest management tools. The industry needs many new active ingredients to replace those that are currently in use but the registration process for these products at the federal or state levels have been slow, in part due to the "minor use" that a crop such as strawberries represents within United States agriculture. An expedited registration for use on strawberries is strongly needed for new chemical pest management tools such as the following:

Hexythiazox (SAVEY) is a miticide that provides control of two-spotted spider mites, a primary pest of strawberries. It has been used successfully in California in recent years under an Emergency Registration (Section 18). Chlorfenapyr (ALERT) and pyridaben (PYRAMITE), are other tools that are needed for mite control by the strawberry industry.

Spinosad (SUCCESS) is a new active ingredient product that is needed for control of western flower thrips, cutworms, beet armyworm and cabbage looper. Chlorfenapyr (ALERT) is needed for use on cutworms and beet armyworms, as well as mites. Methoxyfenozide (INTREPID) is an insect growth regulator needed for control beet armyworm, cutworm and cabbage looper. Imidacloprid (ADMIRE) is a new insecticide that is effect against whitefly, as are pyriproxifen (ESTEEM) and pyridaben (PYRAMITE). Imidacloprid is used in California under an Emergency Registration (Section 18) for control of whitefly. Pyridaben controls whiteflies without disrupting beneficial

insects. These products are needed for mite and insect control in California and resistance management.

Botrytis fruit rot and anthracnose are primary diseases of strawberries in California. Cyprodinil with Fludioxonil (SWITCH) is needed for control of these diseases in California. Use of this reduced risk combination is currently permitted under Emergency Registration (Section 18) in the Southeast United States. Tebuconazole (ELITE) and myclobutanil (RALLY), which is used under an Emergency Registration (Section 18) in California, are needed for control of powdery mildew. Azoxystrobin (QUADRIS) is a new active ingredient product that is also needed for disease control in California. These products are needed as soon as possible in California to control disease and to manage fungicide resistance.

Research Needs - Future Challenges. Research and development into alternate pest management systems that can substitute for the current uses of methyl bromide is clearly the number one future challenge and focus of the industry's research efforts. Methyl bromide use will be significantly reduced beginning in 2001 to 70% in 2003 and will no longer be available for use in 2006. There are no comparable broad-spectrum tools available for control of soil-borne pests and diseases. Methyl bromide has been the key pest management tool for the California strawberry industry for several decades. The strawberry industry faces the challenge of developing sound, multi-faceted, reduced-risk approaches to try to fill the multiple voids that are anticipated with the removal of this single chemical tool.

Other areas of particular research needs are the development of control methods for Western Flower Thrips, mites, and lygus bugs. Diseases of increasing concern to the industry include verticillium wilt and phytophthora crown and root rot though significant increases in the resistance of botrytis fruit rot to existing fungicides has triggered increasing research into new pest management tools and expanded use of IPM use by the industry. Finally, development of weed control methods requires a rapid increase in research methyl bromide has been the primary herbicide tool used by the industry.

PRODUCTION FACTS

- **California's Contribution to Production.** California produces more than 80% of the fresh market and processed strawberries grown in the United States on about 50% of the country's strawberry acreage. California produces about 20% of the world's production (1, 2, 7).
- **Exportation.** California exports about 20% of its strawberry production, accounting for 20% of the world's exported berries. California's primary export destinations are Canada, Japan, and Mexico (1).
- **Acreage.** Bearing strawberries are grown on approximately 22,000 to 25,000 acres per year in California (1, 2, 8, 10).
- **Production and Value.** In 1998, average production in California was 1.5 billion pounds, with an estimated annual value of \$750,000,000 (1, 8).
- **Fresh vs. Processed Markets.** 73% of the strawberry fruit produced are for fresh market and about 27% are for processing (1, 8).
- **Productivity per Acre.** California productivity per acre is over 4 times higher than the productivity in most other states. California produces 49,000 lbs/acre compared to an average of 11,600 lbs/acre for other states and a national average of 29,700 lbs/acre (7). California's productivity is twice that of the state with the second largest production, Florida, and ten times greater than New York production.
- **Cost per Acre.** The cost to produce an acre of strawberries/year amounts to \$9,500 to \$12,000 per acre, pre-harvest (8). The value per acre for harvested strawberries varies based on yield (trays/acre) and quality. Total costs per acre, including harvest costs which typically are \$3.25 per tray of berries, range between \$25,000 and \$30,000 (1, 8).
- **Nursery Stock.** California nurseries supply almost 100 % of strawberry root stock used within California and a significant portion of the stock used as the foundation for strawberries in other states and countries. 1,000,000,000 plants are produced in California nurseries each year. California farmers use 600,000,000 plants annually and 400,000,000 plants are exported to other states, Canada, Europe and Asia (8). The value of this nursery stock is about \$60,000,000.
- **Consumption.** Strawberry consumption is the fourth highest for fruits (8).

PRODUCTION REGIONS

Production Regions. California strawberry production occurs primarily along the central and southern coast, with a small but significant production occurring in the central valley. Fruit production can be divided into five different growing regions. The University of California has defined these regions as follows (6, 8):

1. **Central Coast Region:**
 Comprised of Watsonville, Salinas, Gilroy, Aromas and adjacent areas.
2. **Santa Maria Region:**
 Two-thirds of the total strawberry production acreage is located in the Central Coast and Santa Maria Valley. These regions encompass the coastal regions of Santa Cruz, Santa Clara, Monterey, San Luis Obispo, and northern Santa Barbara counties.
3. **Oxnard Plain Region:**
 Comprised of Oxnard and Ventura County
4. **South Coast Region:**
 One-third of the acreage is planted in southern coastal areas, including the Oxnard Plain and South Coast production areas. The Primary counties involved are Ventura, Orange, Los Angeles, San Diego and western Riverside county.
5. **Interior Valley Regions:**
 About 3% of production comes from interior valleys such as the central San Joaquin Valley (e.g., Fresno and Merced counties).

Nursery Production. Nursery stock are produced in two areas of the state, the Central Valley and in high elevation nurseries in Northeastern California. Central Valley nurseries are primarily located in the Northern San Joaquin Valley and Northern Sacramento Valley. High elevation locations are primarily in the state's Cascade mountain range (6, 8). The valley nurseries supply pest/disease free plantings to the high elevation nurseries, as well as other foreign and domestic nurseries.

Production Schedules by Region. Strawberries are harvested in one or more of the growing areas every month of the year, with peak production occurring in late spring. California strawberry yields are over 50% higher than the national average yield and over 4-fold higher than the other states combined (7). As discussed in this crop profile, effective pest management techniques also contribute significantly to the high productivity of the California strawberry industry. The high production of strawberries in California can be attributed to the yield potential of the cultivars grown, the mild coastal climates that are ideal for strawberries, the use of annual production systems that use pathogen- and pest-free planting stock each year, and the intensive management of the crop with a third of the state's acreage being replanted after a one year rotation to an alternate crop. The high level of crop rotation (about 1/3 of the production acreage) and the high level of new plantings each year result in discrepancies in the statistical estimates of strawberry production per year (1, 2,

4, 7, 8). For example, the Department of Pesticide Regulation's Pesticide Use Database (4) often estimates acreage being about twice as large (42,700 acres were in production at some time during 1996) as the actual acreage being actively used for strawberry production in any given season (25,200 acres of strawberry production were initiated in 1996). This is due to the large number of acreage that are active during at least one period during the calendar year, even though much of the acreage was non-producing for the bulk of the year. Production during the winter months, when the calendar year changes, makes these estimates difficult to make using standard techniques.

CULTURAL PRACTICES

All of California's strawberry acreage is irrigated and most of the crop is grown on an annual basis. Strawberry plants for planting stock are initially grown in the state's nurseries followed by transplantation during the summer or fall. Strawberries are harvested during the following winter, spring, summer and fall. The plants are destroyed after the first harvest season and new plantings are established for subsequent crops. Strawberry plants produce fruit for six months or longer in California. To some extent, berries are picked every month of the year in some area of California.

Nursery Stock Use. California strawberry nurseries produce about 1,000,000,000 runner plants each year, with a farm gate value estimated at about \$60,000,000. California is the world's leading producer of strawberry plants. As a result of climate, geography, modern nursery production and postharvest handling systems, and the Strawberry Certification Program administered by the California Department of Food and Agriculture, California nurseries produce high quality strawberry plants that are marketed to nursery and fruit growers throughout the United States and worldwide. Approximately 15% of production is marketed outside California. For plants sold out-of-state, about 40% are sold for nursery planting stock, and the remainder are sold for fruit production purposes (8).

In California, commercial strawberry plant propagation is a multi-year process. Runner plants produced in one nursery propagation cycle are used as planting stock in the next cycle. The first runner generation is produced in a screen-house, with at least three additional runner generations produced in field nurseries. Two or more field propagation cycles occur in low-elevation (less than 500 ft elevation) nurseries in the state's interior valleys (primarily the Sacramento Valley) where climatic conditions result in prolific runner production during a long growing season. A final field propagation cycle occurs in high-elevation nurseries in northeastern California (at greater than 3,200 ft elevation), where temperature and photoperiodic conditions limit nursery runner production but result in increased transplant vigor, productivity, and fruit quality. Nursery location and nursery production practices effect transplant performance in California strawberry fruit production systems (11).

Nursery stock for summer-planted fields comes from low-elevation nurseries located in the Central Valley. These nursery fields are planted in the mid-Spring and harvested at the end of the calendar year. The resulting nursery stock are trimmed, packaged, and kept in cold storage until transplanting into fields the next summer. High-elevation nurseries are used for fall plantings. In these cases, harvested nursery stock are used immediately for transplanting into production fields.

Fumigation. Several weeks before planting, in essentially all but the organically-grown acreage of the state, the soil is fumigated with a combination of methyl bromide and chloropicrin applied under a sealed plastic tarp, which is removed after about of 5 days (120 hours). Plants are set by hand into deep, narrow holes on pre-moistened beds. If bed fumigation is used, plants are set through holes in

the plastic at least two weeks after fumigation, and the plastic mulch stays in place until the plants are removed. Methyl bromide is scheduled for phase out over a 4 year period due to environmental concerns and will be unavailable after 2005. The consequential rapid replacement of this pest management tool that is currently essential to the industry's productivity will certainly have a major impact on the cultural practices employed by the industry by the middle of the next decade.

Mulch. Mulch can be used to ensure that the strawberries and plant foliage are separated from the ground. This reduces pathogen transfer, enhances soil warming and improves water management. If mulch is used, it is put on immediately after planting. Typically, clear polyethylene mulch is applied to warm the soil, increase early plant growth, and keep the berries off the damp ground. The color of the tarp is important for efficacy and productivity. In Southern California, use of black or colored tarps can reduce weed populations but result in a 10% yield reduction due to less effective soil warming.

Harvesting. The grower/shipper or shipper assumes control of all operations related to harvest. Once harvesting commences, hand-harvesting continues for several months on a 3 to 5 day cycle. This continual harvesting ceases when the productivity of the field diminishes significantly.

Strawberries are harvested carefully by hand and are not subject to washing at the time of harvest. Harvested strawberries are placed in trucks, within an hour or two of picking, which transport the strawberries to a cooling facility. All strawberries are cooled, usually within 1 to 4 hours after harvest. Strawberries are typically forced-air cooled at temperatures of 34°F. Cooling reduces decay and prolongs the fruits shelf-life.

Nearly all strawberries are shipped to the market in refrigerated trucks, and temperatures in the range of 34-36°F are maintained during shipment. The following examples are provided to indicate typical times associated with the harvesting, cooling, and shipping operations:

<u>Time After Harvest</u>	<u>Activity</u>
Day 1	Harvest. Delivery to yard and cooling (1-4 hours).
Day 2-6	Shipping within the United States: To Seattle 1 day To Denver 2 days To Chicago 3 days To New York/Boston 4 days Receiving dock to supermarket: 1 day

Day 2-6	Shipping outside the United States:
	Canada 3-5 days
	Mexico 3-5 days
	Japan (air freight) 1 day

Varieties. Over a dozen major cultivars of strawberries are grown commercially in California. Strawberry cultivars are developed based on several factors including desired day length, fruit size, flavor, appearance, and vigor. Cultivars vary in their susceptibility to some pests and abiotic disorders. The Camarosa strawberry variety is planted in 46% of the state's acreage, with the Selva variety planted in 25% of the acreage. The Chandler variety, which used to account for 40% of the acreage in 1994, is now less than 3% of the production. Proprietary varieties account for 23% of the acreage. The Diamante and Aromas varieties are increasing in popularity (1, 8).

The primary cultivar grown in the central and southern coastal regions is the Camarosa, with this variety accounting for 96%, 72%, and 80% of the acreage in the Orange/San Diego, Oxnard, and Santa Maria districts, respectively. In contrast, this variety is only 10% of the Watsonville/Salinas district and 22% of the San Joaquin Valley district. The Selva and proprietary varieties are primarily used in the Watsonville/Salinas district whereas the Chandler variety is over 78% of the production in the San Joaquin Valley (1, 8). Other cultivars that are grown include the Seascape, Aromas, and Diamante. Specific planting and harvest seasons vary from one growing area to another; however, two planting seasons are used in most areas. Summer plantings usually are made in mid to late summer and fall plantings from mid-October to early November. Summer plantings are grown in the San Joaquin Valley and Southern California.

Cultural Practices. Decisions related to various cultural practices are made daily by growers. Decisions related to field selection, soil nutrient supplements, and cultivars are made well in advance of planting. Fields are graded and planting beds designed to allow proper drainage and irrigation. Clean tillage, raised beds, plastic mulches and water management are all aspects of a systems approach practiced by California strawberry growers.

Crop Rotation. Strawberry fields are sometimes rotated with cover crops such as rye or barley, or another cash crop such as beans, broccoli, lettuce, and cauliflower to reduce pest populations and improve soil structure. Time is allowed from one crop to another to allow crowns from the previous crop to decompose completely. In the south and central coast areas, where land and water costs are high, cover crops are not economically feasible (6, 8).

Sanitary Techniques. Growers use high quality pathogen-free cultivar transplants and the Strawberry Certification Program sponsored by the California Department of Food and Agriculture to help maintain their field free of pathogens. The certification program is based on nursery soil treatment with methyl bromide prior to planting. Growers also practice field sanitation, working the "cleanest" (pathogen free) fields first, rinsing the equipment with hot water to remove soil and plant debris before working another field. Weeds are removed from and around strawberry fields before

they produce seed. Growers also try to ensure that manure or other organic amendments added to the fields have been properly composted or sterilized (6).

Pesticide Application Practices. All applications of pesticides in California are under the control of the growers, and/or their Pest Control Advisor (PCA), or Pest Control Operator (PCO). Growers, PCAs, and PCOs work closely to insure that only registered pesticide products are used and that they are applied in compliance with all state and federal laws, rules and regulations, and labeled recommendations.

Communication between growers, PCAs, and PCOs is maintained during the planting and production periods through frequent field visitations by grower representatives and/or their PCAs. The applicator must inform all affected parties in close proximity to the intended treated area (e.g., harvesting crews, weeding crews, irrigators, etc.) of their intent to apply pesticides in advance of the application and must also post fields and file post-application paperwork with the appropriate state and/or federal agency. Closed systems are also mandatory for the application of Toxicity Category I pesticides in California.

Virus Reduction. Because insect-vectored viruses are so devastating to strawberries, cultural methods have been changed radically to minimize the serious impact of these many viruses. All varieties are produced through a meristem program to remove viruses. Nursery production fields are far removed and isolated from strawberry fruit production regions. In most production regions, annual plantings are used to minimize virus impacts on fruit production, as well as resistance management for insects, mites and fungal diseases.

Organic Production. Organically grown strawberry production is currently less than 0.1% of the total acreage. Reports on production yields per acre from organic fields range from 25% to 60% of the conventional yields (8).

PESTS OF CALIFORNIA STRAWBERRIES

General Comments on Pest Management Summaries

The following sections describe the cultural, biological, and chemical pest management tools that are used by California's strawberry industry to control specific pests. The discussions are presented on a pest-by-pest basis, with "insect" pests being listed first, followed by nematodes, diseases, weeds, and vertebrate pests. The following summaries are based, to a large extent, on the excellent summaries compiled and distributed by the University of California Integrated Pest Management Project. These guidelines were authored by many different specialists and advisors from the University of California's Cooperative Extension. We wish to acknowledge this contribution.

The following pest management summaries are also based on documentation from the UC-IPM Project, the UC Division of Agriculture and Natural Resources, California's Department of Pesticide Regulation, the California Department of Food and Agriculture and the California Strawberry Commission. The summaries are also based on extensive comments and suggestions from experts from the agricultural community. Their practical input has made the details within these summaries possible.

Use of DPR Pesticide Use Database.

Except where otherwise noted, the pesticide use data presented in the following summaries are based on the Department of Pesticide Regulation's (DPR) 1996 Pesticide Use Report (4). We have modified the percent of crop treated values reported by the DPR. In determining the total acres planted in 1996, the DPR's data base added up all the separate acreage that reported at least one pesticide application in calendar year 1996. This calculated to be 42,715 acres (4). The California Strawberry Commission reports that 25,245 acres of strawberries were planted that same year (8). The discrepancy between the two figures is that the DPR estimate does not account for the acreage that is planted at the end of one calendar year and harvested in the next. Since a significant portion of the acreage is rotated through other crops, the acreage is over estimated in the DPR data base for strawberries. We have corrected the percent usage numbers by using 25,245 acres as the bases for these calculations (8).

Soil-Borne Pest Management and Methyl Bromide.

The following pest management summaries are presented on a pest-by-pest bases. However, since one single pest management tool, methyl bromide, is used extensively by California's strawberry industry to control a wide variety of soil-borne pests, we thought a separate discussion of this chemical's use and impact, separate from any pest-specific discussion, would be appropriate.

Methyl bromide, a broad-spectrum pesticide, needs to be discussed in a general section that is not specific to any individual pest. Methyl bromide in combination with chloropicrin is used to produce all of California nursery stock, including planting stock intended for organic production, and is used on essentially all of California's production strawberry acreage, with the exception of acreage used to produce organically-grown fruit or are part of grower trials to assess pest management strategies in the absence of methyl bromide.

The effectiveness of the broad-spectrum of targets for methyl bromide/chloropicrin pre-plant fumigation makes it difficult to discuss this pest management tool in the sole context of the individual pests listed in the following sections. This combination pre-plant fumigation has proven efficacious against diseases such as soil-borne fungi that cause verticillium wilt, *Phytophthora* root and crown rots, anthracnose, black root rot, charcoal rot, and, significantly, other soil-borne pathogens of unknown etiology that impact strawberry plant yield and quality. Methyl bromide/chloropicrin treatments are also effective for control of arthropods (such as root weevils, cutworms, strawberry rootworm, white grubs, garden symphylan, and ground mealybug), nematodes (such as foliar and root-knot nematodes), and weed seeds of all species (with rare exceptions such as field bindweed, little mallow, burclover, sweetclovers and filaree). Research has shown that increased plant vigor due to methyl bromide/chloropicrin fumigation allows plants to withstand more intensive spider mite pressure with less yield reduction than is observed without this fumigation.

The use of methyl bromide/chloropicrin provides early root development and plant vigor stimulated by the suppression of diseases in the soil and is a critical element in Integrated Pest Management strategies throughout the season. It has been shown to double yields when no known pathogens or pests are present in the soil, due to methyl bromide/chloropicrin fumigation (12).

Methyl bromide has properties that have been identified as being problematic to both the environment and public health and, as a result, it will be phased out of production and use by the year 2006, with a 70% reduction in use in 2003. There are no broad-spectrum soil fumigant alternatives comparable to methyl bromide that are currently available to the strawberry industry. No other product is ready for widespread use and no product has appeared that can fully replace the wide-spectrum of control that is currently provided through the use of methyl bromide. The use of methyl bromide as a key pest management tool has resulted in relative economic stability for the California strawberry industry for many years. With the impending loss of methyl bromide as a pest management tool, the strawberry industry faces the challenge of developing a sound, multi-faceted, reduced-risk approach to integrated pest management that will provide viable biological controls, cultural practices and chemical tools for disease, insect and weed control. The continued economic success of the strawberry industry in California will be based, in part, on the industry's ability to develop a pest management program that balances sound cultural and biological control practices with chemical treatment.

Alternates to methyl bromide being assessed currently include the fumigants chloropicrin (alone), metam sodium, and 1,3-dichloropropene plus chloropicrin (TELONE C-35). Narrow spectrum

chemical tools are also being tested to substitute for parts of the wide array of pest control solutions that methyl bromide currently provides. For example, pesticides such as hexythiazox (SAVEY) may substitute for some of the miticidal properties of methyl bromide and insect growth regulators may substitute for some of the insecticidal properties of methyl bromide; however, other chemical tools would still be needed to reduce losses from mites, botrytis, powdery mildew and other foliar diseases and pests in the absence of methyl bromide. Enhanced use of cultural techniques such as mulching, solarization and plant breeding are also being studied. It is clear that, for California's strawberry industry, many different chemical and cultural tools will be needed in the near future to substitute for this single pest management ingredient.

The loss of methyl bromide will have a significant impact on many of the following discussions of pests, their severity, and the effectiveness of pest management tools to control their adverse effects.

PRIMARY INSECT PESTS

It is important to note that all discussions related to insect control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

TWOSPOTTED SPIDER MITE

Tetranychus urticae

Damage. The twospotted spider mite is a serious pest of strawberries in all California growing areas. Twospotted spider mite damage to strawberries is expressed as stippling, scarring, and bronzing of the leaves and calyx. Twospotted spider mite feeding seriously interrupts photosynthesis and is particularly damaging during the first 4 to 5 months following transplanting, in late summer, fall, or early spring, depending on the growing region. Mite feeding during this critical period of plant growth substantially reduces berry numbers per plant and overall yield. Plants are less sensitive to mite feeding after initial berry set but yield loss can be significant at all mite infestation levels exceeding one mite per leaflet. Substantial yield loss can result from densities exceeding 5 to 10 mites per leaflets until mid-spring, and 20 mites per leaflet or more thereafter. Plants that sustain infestations of greater than 75 mites per leaflet may become severely weakened and appear stunted, dry, and reddish.

Description of Pest. Twospotted spider mites are typically found on the bottom surface of strawberry leaves. Mating and egg laying behaviors are typically observed in all coastal strawberry growing regions year round. The highest mite populations are often observed following the spring fruit harvest, and this peak is typically followed by a rapid, natural decline in mite density.

Monitoring. Growers monitor the twospotted spider mite pressure within the field to determine if they are being maintained below economically injurious levels. Vigorous plant growth during the first 4 to 6 months following fall transplant is a key factor in strawberry production. More than 80% of strawberry acreage is fall-planted and mite control during the first 4-6 months is critical when the effectiveness of many technologies (i.e. predators, AVID, VENDEX) is marginal. During this critical period, mite feeding is extremely damaging and the established economic threshold is five or fewer mites per mid-tier leaflet. *Tetranychus cinnabarinus* is a close relative of the twospotted spider mite and should be identified correctly. It is commonly found at low densities but has only been reported as damaging in San Joaquin Valley growing regions.

CONTROLS

Cultural

Vigorous Cultivars. Damage by twospotted spider mites is minimized by using cultural practices that favor vigorous plants. Strawberry cultivars vary in susceptibility to twospotted spider mite infestation and tolerance of twospotted spider mite feeding.

Chilling. Plants with insufficient amounts of chilling will have low vigor and will often develop intolerable mite infestations. Excessive chilling will promote increased vigor and reduce mite abundance, but other production factors are affected adversely (i.e., delayed flowering, large plant size, increased vegetative runner production).

Crop Rotation. Crop free periods can potentially reduce the rate at which spider mite populations become resistant to miticides.

Dust Reduction. Road dust control is important in inhibiting mite infestations, as dusty conditions favor the buildup and dispersal of twospotted spider mites.

Other Factors. Fall transplant, nursery location, preharvest chilling, nursery harvest date, and length of pretransplant supplemental cold storage can all affect a plant's productivity. Other controllable factors affecting plant vigor are soil preparation and fumigation, fertilization, and use of polyethylene plastic mulch and the color of the plastic.

Biological

Predator Mites. Biological control alone rarely provides control of spider mites sufficient to prevent yield loss. Biological control methods are typically used in conjunction with chemical pest management techniques, as chemical miticide treatments reduce strawberry yield loss due to spider mites about 4 times over fields relying strictly on predator control. In the Oxnard Plain region, for example, predator mite introductions typically follow applications of miticides such as hexythiazox (SAVEY). Predator mites such as *Phytoseiulus persimilis*, *Galendromus occidentalis*, and *Amblyseius californicus* are commercially available for release. Inoculative releases (i.e., initial releases of a small number of predators) are made when twospotted spider mites are first found in the field. Inoculative releases into hot spots within the field may also aid in suppressing infestations. Subsequent inundative releases of predaceous mites may also help to reduce twospotted spider mite infestations. Another predator mite, *Phytoseiulus macropilus*, occasionally occurs in strawberries early in spring. The success of predator mites is strongly influenced by meteorological factors, such as rainfall and temperature.

General Predators. Other natural enemies include minute pirate bugs (*Orius tristicolor*), a small black lady beetle (*Stethorus* spp.), a small black rove beetle (*Oligigota oviformis*), bigeyed bugs (*Geocoris* spp.), brown lacewing (*Hemerobius* spp.), green lacewing (*Chrysopa* spp.), sixspotted thrips (*Scolothrips sexmaculatus*), damsel bugs (*Nabis* spp.), and a cecidomyiid fly maggot (*Feltiella acarivora*).

Chemical

Twospotted spider mites have a history of developing resistance to miticides rapidly when a miticide is applied repeatedly to the same population. Alternating the use of miticides that have different modes of action helps reduce the development of resistance to a specific miticide. Organophosphate, carbamate, and pyrethroid insecticide applications can stimulate twospotted spider mite outbreaks by disrupting the balance with beneficial insects.

Hexythiazox. 3 day PHI. Hexythiazox (SAVEY) has been used under Emergency Exemption registrations (Section 18 registrations) in recent years. The typical use rate is 0.1 lb ai per acre. It is often used in rotation with other miticides to reduce development of resistance. This use was not allowed on strawberry nurseries. The restricted-entry interval for hexythiazox is 12 hours.

Avermectin. 3 day PHI. Avermectin (a.k.a., abamectin)(AGRI-MEK) is applied at a average rate of 0.02 lb ai per acre. It is applied to about 75% of strawberry acreage, with an average of 2 applications per field annually. Avermectin is less effective under cold weather conditions. Two applications are made 7 to 10 days apart when mites reach detectable levels under warmer temperatures in late winter/spring. A maximum of 4 applications (two paired treatments) is permitted in a growing season. Avermectin is not registered for strawberry nurseries. The restricted- entry interval for avermectin is 12 hours.

Fenbutatin-oxide. 1 day PHI. Fenbutatin-oxide (VENDEX) is applied at an average rate of 1.2 lbs ai per acre to around 17% of strawberry acres. It is primarily used in the Central Valley production fields. Most uses are a single application per season. Pest resistance to fenbutatin-oxide has been widely reported and persists within a population. Two applications can be effective but resistance again becomes prevalent in the surviving twospotted spider mite population. Fenbutatin-oxide works poorly under cool conditions. The restricted-entry interval for fenbutatin-oxide is 48 hours.

Narrow Range Oil. 0 day PHI. Narrow range oil is typically applied at a dilutions containing 1-2% oil to less than 10% of strawberry acres. This material is used for low to moderate infestations. Higher pest pressure requires the use of a more effective miticide. Narrow range oils are not used from peak bloom through fruiting period or when temperatures exceed 75°F. Narrow range oils are often used in rotation with avermectin to

help prevent avermectin resistance. There is a danger of phytotoxicity when oils are used. There is no restricted reentry period.

Dicofol. 3 day PHI. Dicofol (KELTHANE) is an organochlorine applied at an average rate of 1.2 lbs ai per acre. Dicofol is applied to approximately 20% of treated acres of strawberries per year with most fields being treated just once. It is most widely used for spider mite control in the Central Valley production fields. Pest resistance to dicofol is widespread. Dicofol can be effective at controlling twospotted spider mites following an extended period of no use. Because this material is one of the few remaining miticides registered for use on and effective against cyclamen mite, it is not typically applied to control twospotted spider mite and is used sparingly for cyclamen mite control. Dicofol is toxic to predaceous mites but is relatively nontoxic to beneficial insects. Dicofol has a restricted-entry interval of 12 hours.

Rotenone. 0 day PHI. Rotenone, a naturally derived substance from cube root, is sometimes used for control of twospotted spider mites, but is less effective and more expensive than other available products. Rotenone is applied to about 4% of the acreage at an average rate of 0.01 lb ai per acre. It is extremely toxic to fish. Rotenone can be used by organic growers. There is a 12 hour restricted entry interval for rotenone.

Fenpropathrin. 2 day PHI. Although registered for use on twospotted spider mites, the synthetic pyrethroid fenpropathrin (DANITOL) is not typically used for its control. Lygus bugs should be the primary target pest for this material and impacts on the mite populations would be secondary to the targeted use against other pests. In fact, severe mite resurgence can occur following its use. There is concern that excessive use of synthetic pyrethroids, like fenpropathrin, may lead to the development of pest resistance in both spider mites and lygus bugs. The restricted reentry period for fenpropathrin is 24 hours.

Bifenthrin. 0 day PHI. The synthetic pyrethroid bifenthrin (BRIGADE) is not typically used for control of the twospotted spider mite. Lygus bugs should be the primary target pest for this material. There is concern that excessive use of synthetic pyrethroids, like fenpropathrin and bifenthrin, may lead to the development of pest resistance in both spider mites and lygus bugs. Severe mite resurgence can occur following their use. Bifenthrin is a relatively new chemical tool available to California growers and is applied at a rate of 0.1-0.2 lbs ai/acre. The restricted reentry period is 12 hours.

The following active ingredients are not currently registered for use on strawberries but are needed tools as soon as possible. An expedited registration is encouraged by the industry.

Chlorfenapyr. Chlorfenapyr (ALERT) is not currently registered for use on strawberries but is needed as soon as possible for mite control by the strawberry industry.

Pyridaben. Pyridaben (PYRAMITE) is not currently registered for use on strawberries but could be an effective tool for the strawberry industry against moderate mite populations. It is not as effective as avermectin or another yet to be registered product (chlorfenapyr) against high mite population.

LYGUS BUGS

Lygus hesperus

Damage. Lygus bugs are one of the causes of irregularly-shaped, cat-faced strawberries. Lygus bugs damage fruit by puncturing individual seeds; this, in turn, stops development of the berry in the area surrounding the feeding site. Lygus bugs are a serious pest in central strawberry-growing areas (interior valleys, central coast, Santa Maria Valley regions) where strawberries are typically grown past May and through the summer months, but are rarely pests in southern California, where the fresh market berry harvest is generally complete by the end of May.

Description of Pest. Adult Lygus bugs are about 0.25 inch long. Immature forms of lygus bugs are as damaging as adults. The larger nymphs (immature forms) are pale green and look somewhat like an aphid. They can be distinguished from aphids by their more rapid movements. Lygus bugs lay eggs in weeds in January, which then hatch in March.

Monitoring. Monitoring fields for nymphs and adult lygus bugs is critical in their control. There are two major monitoring periods for lygus bugs in strawberries grown in central and northern California. Infestations in southern California strawberry fields are rare. Early in the season, growers monitor for the first appearance of lygus nymphs on weed hosts. Lygus bugs can be active all winter. Monitoring for adults begins in mid-April to detect when adults first appear in the field.

CONTROLS

Cultural

Weed Control. Successful management of lygus bugs includes control of weed hosts during the winter months, monitoring for the appearance of lygus nymphs on weed hosts. Weed control along roadways, ditches, and field borders helps prevent spring buildup of lygus bugs. Weed control is carried out in March and early April while lygus are still nymphs. Once adults are present on weeds, they migrate into strawberries when the weeds are removed. Infestations by lygus bugs may become more severe without the preplant use of methyl bromide since the weed populations are likely to increase.

Vacuuming. Growers experimented with suction devices (bug-vacs) to control lygus bug with some success (reduction of adult populations by 75% and nymphs by 9-50%), but this is not a common cultural practice at this time. Damage from lygus bugs occurs at such low populations that this technique did not adequately reduce damage to the crops. If lygus bug population levels are moderate to heavy, overall damage to the crop is only reduced by 10% through vacuuming (9).

Biological

General Predators. Bigeyed bugs (*Geocoris*) are the most important natural enemy of lygus bugs. They feed on eggs and young nymphs. Damsel bugs also feed on eggs and nymphs, and minute pirate bugs feed on lygus eggs. None of these natural enemies; however, is successful in keeping lygus from reaching damaging levels when there is a heavy migration of adults into strawberry fields when wild vegetation dries up in the spring.

***Anaphes iole*.** A parasitic wasp, *Anaphes iole*, which attacks lygus eggs, is available commercially and can be used for inoculative releases. It can reduce lygus populations in strawberry fields, but because thresholds for this pest are very low, economically acceptable results have not been achieved.

Chemical

Chemical treatments are applied to control lygus when they are at the most susceptible first and second instar nymph stages. Insecticides applied to later nymphal stages and adults are much less effective. Short residue insecticides do not control lygus bugs, necessitating repeated applications.

Malathion. 3 day PHI. Malathion is the most important treatment for lygus immediately after hatching. This chemical works well in IPM programs. Malathion is only effective against the first 3 nymphal instars. Effective control requires multiple applications, as residual is short-lived. Very high levels of lygus bug resistance to this material have been identified in some growing areas. Malathion is applied at an average rate of almost 2 lbs ai per acre to about 55% of strawberry acreage. Statewide, the number of repeat malathion applications per year is 4. The restricted-entry interval for malathion is 12 hours.

Fenpropathrin. 2 day PHI. Synthetic pyrethroids such as fenpropathrin (DANITOL) are best when used late in the season due, in part, to their disruption of beneficial insects and the resulting infestations from other pests, especially spider mites. Pyrethroids are the most effective materials currently registered for lygus bug control in strawberries but the potential for the development of resistance to these insecticides is high. There is concern that excessive use of synthetic pyrethroids, like fenpropathrin, may lead to the development of insecticide resistance in both spider mites and lygus bugs. Lygus bugs should be the primary

target pest for this material. Fenpropathrin was applied at an average rate of 0.4 lb ai per acre onto about 14% of strawberry acreage in 1996, with an average of 1 application per season though 2 applications/year are allowed. The restricted-entry interval for fenpropathrin is 24 hours.

Bifenthrin. 0 day PHI. Bifenthrin (BRIGADE) is a relatively new tool available to California strawberry growers and is applied at a rate of 0.04 to 0.2 lbs ai/acre. Synthetic pyrethroids such as bifenthrin are best when used late in the season due, in part, to their disruption of beneficial insects and the resulting infestations from other pests, especially spider mites. Pyrethroids are the most effective materials currently registered for lygus control in strawberries but the potential for the development of insecticide resistance is high. Although this material can suppress spider mites, it should be used primarily to control lygus bugs. Use of bifenthrin is limited to 2 applications/year. Applications made early in the season can lead to severe spider mite outbreaks later in the season. The restricted-entry interval for bifenthrin is 12 hours.

Pyrethrin and Piperonyl Butoxide. 0 day PHI. This combination of pyrethrins and piperonyl butoxide (PYRENONE) is applied at label rates to strawberry fields. Though not as disruptive as the synthetic pyrethroids, late season applications are preferred. This combination is variable in its effectiveness against lygus bugs. The restricted-entry interval for pyrethrin and piperonyl butoxide is 12 hours.

Naled. 1 day PHI. Naled (DIBROM) is an organophosphate that is applied at rates of about 1 lb ai per acre. In tank mixes, naled can be used at lower rates, typically half the normal application rate. It was applied to about 18% of the state's acreage. When used, naled is typically applied once a year. Naled provides good late season control, but is not used when temperatures exceed 85°F due to plant phytotoxicity. Use is typically limited to regions where the end of the season is cool. The restricted-entry interval for naled is 24 hours.

Methomyl. 3 day PHI for fresh and 10 day PHI for processing strawberries. Methomyl (LANNATE) is a carbamate that is used to control lygus bugs when populations are high and other treatments have not been successful. Average applications are about 0.8 lb ai per acre with an average of 1 application per season. Methomyl was applied to about 25% of strawberry acreage in 1996. There is a 2 day restricted-entry interval for methomyl.

Insecticidal Soap. 0 day PHI. A single application of insecticidal soaps can reduce nymphal populations by about 50%, but have little effect on adults. It also kills about 50% of predatory mite eggs, but does not affect motile predators. There is no restricted entry interval.

Diazinon. 5 day PHI. Diazinon is applied to strawberry fields at an average rate of about 0.8 lb ai per acre with an average of 1 application per year. It may injure mite predators,

resulting in an increase of twospotted spider mites. Diazinon is used to treat about 8% of strawberry acres. The restricted-entry interval following applications is 24 hours.

CYCLAMEN MITE

Steneotarsonemus pallidus

Damage. The cyclamen mite is an important pest of central coast strawberries. It has become a less significant problem as fewer strawberry fields are retained for multiple season use due to the shift to annual plantings. Leaves heavily infested with cyclamen mites become severely stunted and crinkled, resulting in a compact leaf mass in the center of the plant. Feeding on flowers can cause them to wither and die. Fruit on infested plants is dwarfed, and the seeds stand out on the flesh of the berry. When uncontrolled, this mite can prevent plants from producing fruit.

Description of Pest. At low population densities, cyclamen mites are usually found along the midvein of young unfolded leaves and under the calyx of newly emerged flower buds; when populations increase, these mites can be found anywhere on non-expanded plant tissue. Cyclamen mites are primarily pests in second year plantings and are not visible to the naked eye. Adult female cyclamen mites overwinter in the strawberry crown.

Monitoring. Growers monitor unfolding leaves to identify the presence of mites. When one cyclamen mite/10 leaves is identified chemical treatment is indicated.

CONTROLS

Cultural

Precautions in Transportation. Cyclamen mites can easily be transferred from one location to another by field workers, bees, birds, and equipment, including strawberry freezer trays. Cyclamen mite infested nursery plants can be a source of this pest in strawberry production areas. Growers should insist upon uninfested nursery stock. When nursery stock plants are known to be infested by cyclamen mites, they are treated in hot water at 100°F for 30 minutes before planting. Freezer trays are also dipped in hot water between fields. Fresh clothing for field workers is also recommended.

Crop Rotation. Second year plantings, particularly those in infested fields, should be avoided in problem areas (problem area locations are rotated through other crops). To slow the spread of infestations, infested plants are removed as soon as symptoms appear.

Dust Reduction. Road and field dust reduction can also be important in inhibiting mite infestation. Dusty plants are a more desirable habitat for these pests. Roads and adjacent areas can be watered down.

Biological

General Predators. Two natural predator mites of cyclamen mite are *Typhlodromus bellinus* and *Typhlodromus reticulatus*, but they often do not provide economic control and are easily disrupted by insecticides. The sixspotted thrips can be an important natural enemy since this thrips can feed on cyclamen mites when they become very prevalent.

Chemical

To control cyclamen mites, a high rate of water per acre (300-500 gal) is necessary to soak the unfolded leaves and immature flower buds located in the crowns. Growers sometimes remove or treat infested hot spots by hand-sprayer to suppress infestations to avoid treating the entire field. In nurseries, early-season control before the plant canopy closes over is critical. Use of certified pest and disease free nursery stock is a key to control.

Avermectin. 3 day PHI. Avermectin (AGRI-MEK) is applied at an average rate of 0.01 lb ai/acre with sufficient water to soak the material into the crown of the plant. It is applied to about 75% of strawberry acreage (though it can be targeted to control several important strawberry pests). Avermectin works poorly under cold weather conditions. Most fields have two applications per season. Avermectin is not registered for use in strawberry nurseries. The restricted-entry interval is 12 hours.

Dicofol. 3 day PHI. Dicofol (KELTHANE) is an organochlorine applied with a wetting agent at an average rate of about 1.2 lb ai/acre in 400-600 gallons of water to soak the material into the crown of the plant. Dicofol is applied to approximately 20% of strawberry acreage with an average of 1 application per season and is very effective against cyclamen mite. Dicofol is toxic to predaceous mites but is relatively nontoxic to beneficial insects. The restricted-entry interval is 12 hours.

Endosulfan. 4 day PHI. Endosulfan is an organochlorine applied at a rate of about 1 lb ai/acre in 400 to 600 gallons of water to soak the material into the crown of the plant. Endosulfan is applied to about 4% of strawberry acreage with an average of 1 application per year. Some counties are restricting the percent of acres that can be treated with endosulfan and as a result most farmers cannot use endosulfan due to organochlorine and water related issues. Reapplications are not made within 35 days. Single applications per year are the norm with no more than 2 applications being performed on any field, even though 3 applications per year are allowed. The restricted-entry interval for endosulfan is 24 hours.

Diazinon. 5 day PHI. Diazinon is an organophosphate that is applied to strawberry fields at an average rate of about 0.8 lb ai per acre with an average of 1 application per year. It may injure mite predators, resulting in an increase in pest mites. Diazinon is used to treat about 8% of strawberry acres. The restricted-entry interval following applications is 24 hours.

Carbaryl. 7 day PHI. Carbaryl (SEVIN) is a broad-spectrum carbamate applied to strawberry beds around the base of the plants at an average rate of 1.6 lb ai/acre. The product can be harsh on beneficials and result in spider mite outbreaks. Carbaryl is applied to approximately 25% of strawberry acres. The restricted-entry interval for carbaryl is 12 hours.

APHIDS

Strawberry Aphid: *Chaetosiphon fragaefolii*

Melon Aphid: *Aphis gossypii*

Green Peach Aphid: *Myzus persicae*

Potato Aphid: *Macrosiphum euphorbiae*

Damage. Aphid damage to berries occurs in all growing regions. Aphid damage is less critical in the central coastal region where aphid populations typically are not as high. Aphids occasionally cause yield losses in California strawberries because of their honeydew production. Honeydew deposits on fruit cause sooty molds to develop and the white skins shed by aphid nymphs to stick to the fruit. This contamination renders the fruit unmarketable as fresh fruit. Also, aphids transmit several viruses that can cause significant economic losses in perennial strawberries. Aphid control is also crucial in strawberry nurseries to reduce the possibility of virus transmission.

Description of Pest. Populations of aphids usually begin to reach potentially damaging levels in California during late January or February. Populations undergo a natural decline, usually to noneconomic levels, during May and June. Strawberry aphid, typically the most common species of aphid found on strawberries, is pale green to yellowish in color. The melon aphid, the second most common species on strawberry, is often the first to migrate into the strawberry fields each season. Green peach aphid and potato aphid rarely account for more than 10% of the total aphid populations in the field. The potato aphid is much larger than the other species and has both a pink form and a green form in California.

Monitoring. Growers measure the percent aphid infestation by sampling trifoliate leaves. If infestation reaches a threshold, chemical treatment becomes necessary to minimize economic losses.

CONTROLS

Cultural

Plastic Covers. Some row covers (plastic tunnels or Remay-type enclosures) have reduced aphid populations to below economic levels. The cost of row covers are substantial and the economic viability for large- or small-scale plantings has not been established.

Dust Reduction. Road and field dust reduction can also be important in inhibiting aphid infestation. Dusty plants are a more desirable habitat for these pests. Roads and adjacent areas can be watered down. Controlling dust is important to facilitate parasite and predator activity.

Biological

Parasites and Predators. Natural enemies of aphids include parasitic wasps, *Lysiphlebus testaceipes*, *Aphidius*, *Aphelinus*; fungal disease; *Entomophthora*; lacewings; bigeyed bugs, minute pirate bugs, dustywings (*Coniopterygidae*); damsel bugs; and ladybugs. In some circumstances the levels of biological control can be economically viable, such as with the case of the melon aphid in southern California strawberry-growing regions.

Chemical

Chemical treatments are made when aphid pest pressure reaches a trigger level (sometimes this trigger is when 30% of young trifoliated leaves are infected). Trigger levels can be selected to minimize the impact on beneficial insects in the fields.

Diazinon. 5 days PHI. Diazinon is the most desirable chemical treatment for aphids on strawberries. Diazinon is applied at an average rate of about 0.8 lb ai/acre an average of 1 application per season though multiple applications are allowed. Diazinon is used to treat around 8% of strawberry acreage. It provides longer residual activity than soap does. It may injure mite predators, resulting in an increase of twospotted spider mites. The restricted-entry interval for diazinon is 24 hours.

Malathion. 3 day PHI. Malathion is another treatment for aphids though not as commonly used for this pest as diazinon. This chemical works well in IPM programs. Effective control requires multiple applications, as residual is short-lived. Statewide, the number of repeat malathion applications per year is 4, but these applications often target lygus bugs. Very high levels of resistance to this material have been identified in some growing areas. Malathion is applied at an average rate of almost 2 lbs ai per acre to about 55% of strawberry acreage. The restricted-entry interval for malathion is 12 hours.

Naled. 1 day PHI. Naled (DIBROM) is an organophosphate that is applied at rates of about 1 lb ai per acre. It was applied to about 18% of the state's acreage, normally with only a single application per year. Naled provides good late season aphid control but is not used when temperatures exceed 85°F due to plant phytotoxicity. Naled is typically limited to regions where the end of the season is cool. The restricted-entry interval for naled is 24 hours.

Insecticidal Soap. 0 day PHI. Insecticidal soaps are applied at rates of about 5.5 lb ai/acre, depending on the soap used. Insecticidal soaps are applied to approximately 10% of strawberry acres. No more than 2 applications/season are typically made because phytotoxicity may occur to the plants. Typically, a single application is made per season. In addition to aphids, these treatments also kill about 50% of predatory mite eggs, but does not affect motile mites. There is no restricted reentry period.

ROOT WEEVILS

Cribrate Weevil: *Otiorhynchus cribricollis*

Woods Weevil: *Nemocestes incomptus*

Black Vine Weevil: *Otiorhynchus sulcatus*

Fuller Rose Weevil: *Pantomorus cervinus*

Damage. Root weevil larvae feed on the roots of strawberry plants and can completely devour small rootlets and destroy the bark and cortex of larger roots. Soon after feeding begins, plants wilt because the roots can no longer provide moisture for leaves. It is not uncommon to find weevil larvae that have penetrated into the lower portion of the plant's crown. These pests caused major economic damage in the 1950s prior to the onset of methyl bromide use. As a result, root weevils are anticipated to become an increasingly important pest in the next few years as methyl bromide is removed from the marketplace.

Description of Pest. Adult root weevils are beetles. They feed at night and hide around the crowns of plants during the day; they cannot fly. Adults feed on foliage and remove large scallops from the leaves. Such leaf damage is a good indication that weevils are present, but is not economically damaging to the plants. The adults, nearly all females, emerge in late spring or summer and feed on strawberry foliage. Eggs laid on the plants, after hatching, work their way into the soil and feed on strawberry roots and crowns. In spring, they resume feeding and can cause extensive damage before they pupate. Root weevils have a single generation each year.

Monitoring. Observations for infestation such as crown damage. Though some damage is acceptable, severe damage triggers control methods.

CONTROLS

Cultural

Crop Rotation. Annual plantings reduce the likelihood of high populations building up in fields. Crop rotation with non-host cover or cash crops may also help to reduce infestations.

Sticky Barriers. Sticky barriers are used to prevent movement of adult weevils from infested second year berries and host areas to newly fumigated plantings. Adult weevils overwinter in nearby native plants, ornamentals, blackberries or in second-year strawberries.

Weed-Host Control. Control of host plants adjacent to fields helps to reduce the potential for infestation.

Biological

No known biological controls of root weevils.

Chemical.

Soil Fumigation - General. Soil fumigation with methyl bromide and chloropicrin for weed and disease control has greatly reduced the presence and effect of root weevils. Prior to the use of methyl bromide, root weevils were a major economic pest of strawberries. Currently, root weevils require management only in a few central coast locations. However, with the impending loss of methyl bromide as a soil fumigant, it may be anticipated that root weevil management throughout the growing regions will increase. None of the currently registered chemicals will control these weevil larvae.

Methyl Bromide/Chloropicrin. 0 day PHI. Methyl Bromide with chloropicrin is applied as a preplant application, approximately 30 days prior to planting, to fields at a rate of 300 to 400 lbs ai combination/acre. It is applied to essentially all of the conventionally grown strawberry fields in California for control of pathogenic fungi, weeds, and nematodes. Methyl bromide is a restricted use material that may only be applied by permit from the county agricultural commissioner. Many use restrictions apply. The restricted entry interval for methyl bromide is 48 hours.

For the following non-fumigant treatments, large application rates and ample water are needed to ensure penetration into the soil-based habitats of root weevils.

Diazinon. 5 days PHI. Diazinon is applied to strawberry fields at an average rate of about 0.8 lb ai/acre. Rates used to control root weevil are typically higher. It is registered for use

on strawberries to control root weevils but is not very effective compared to the fumigants. It may injure mite predators, resulting in an increase of twospotted spider mites. Diazinon is used to treat approximately 8% of strawberry acreage. The restricted-entry interval for diazinon is 24 hours.

Bifenthrin. 0 day PHI. Bifenthrin (BRIGADE) is a relatively new chemical tool available to California strawberry growers and is applied at a rate of 0.05 to 0.2 lbs ai/acre to control root weevil. Synthetic pyrethroids such as bifenthrin are best when used at or near the end of the season due, in part, to their disruption of beneficial insects and predatory mites and the resulting infestations from other pests. This may not be the optimal treatment timing to achieve control. High application rates are needed to impact root weevil damage. For control, bifenthrin applications must be made early in the development of the weevil infestation. Although this material can impact root weevils, it is used primarily to control lygus bugs. Use of bifenthrin is limited to 2 applications/year. The restricted-entry period for bifenthrin is 12 hours.

Methomyl. 3 day PHI for fresh and 10 day PHI for processing strawberries. Methomyl (LANNATE) is a carbamate that can be used to control root weevils when populations are anticipated to be high. Average methomyl applications are about 0.8 lb ai per acre with an average of 1 application per season though application rates to control root weevils need to be high. Methomyl was applied to about 25% of strawberry acreage in 1996. The restricted entry interval for methomyl is 2 days.

Chlorpyrifos. 45 day PHI. Chlorpyrifos (LORSBAN) is a broad-spectrum insecticidal organophosphate applied at an average rate of about 1 lb ai/acre to approximately 15 % of strawberry acreage though applications of this insecticide can be targeted toward many pests, not just root weevil. Higher application rates are typically needed to control root weevils. Chlorpyrifos is critical for weevil control in southern California. The restricted-entry interval for chlorpyrifos is 24 hours.

Carbofuran. 30 day PHI. Carbofuran (FURADAN) is a carbamate that can be used to control root weevils. Limited applications (less than 0.1% of strawberry acreage) of carbofuran were made in California. Application rates are about 2 lbs ai per acre. The restricted entry interval for carbofuran is 24 hours.

WESTERN FLOWER THRIPS

Frankliniella occidentalis

Damage. Damage from thrips has increased in recent years. Damage, which rarely became economically significant in past years, is impacting yield and quality. When very abundant, more than 10 thrips per blossom, fruit can be seriously discolored (bronzed). Thrips feeding on strawberry

blossoms causes the stigmas and anthers to turn brown and wither prematurely, though not before fertilization has occurred. As fruit develops, thrips feeding may cause a russetting of the fruit around the cap, but this type of injury is seldom economic.

Description of Pest. Western flower thrips are slender, very small insects. Flower thrips populations build up on alfalfa, weeds, and other vegetation in spring, and then move from these hosts when they are cut or dry up.

Monitoring. Control is necessary when western flower thrips are very high (typically a trigger of 10 thrips per flower).

CONTROLS

Cultural

Weed Control. Weed and vegetation management adjacent to berry fields helps to reduce thrips populations. Growers monitor for thrips by randomly collecting flower blossoms into a glass container with several drops of an insect-killing material soaked into cotton and then by counting the thrips.

Biological

Predators. Minute pirate bugs feed on thrips. It should be noted that thrips have been observed feeding on twospotted spider and cyclamen mites.

Chemical

Chemical control methods are only necessary when thrips become very high.

Methomyl. 3 day PHI for fresh strawberries. 10 day PHI for processing strawberries. Methomyl (LANNATE) may be applied at a rate of less than 1 lb ai per acre. Methomyl is applied to 25% of strawberry acreage though this product is used to manage many other strawberry pests and not typically thrips. This percentage covers several pests that methomyl is used to control. The restricted-entry interval for methomyl is 48 hours.

Pyrethrin and Piperonyl Butoxide. 0 day PHI. This combination of pyrethrins and piperonyl butoxide (PYRENONE) is applied at label rates to strawberry fields. Though not as disruptive as the synthetic pyrethroids, late season applications are preferred. This combination is variable in its effectiveness. The restricted-entry interval for pyrethrin and piperonyl butoxide is 12 hours.

Naled. 1 day PHI. Naled (DIBROM) is an organophosphate that is applied at rates of about 1 lb ai per acre. It was applied to about 18% of the state's acreage. When used naled is typically applied once a year. Naled provides good late season insect control but is not used when temperatures exceed 85°F due to phytotoxicity. Use is typically limited to regions where the end of the season is cool. The restricted-entry interval for naled is 24 hours.

The following active ingredient is not currently registered for use on strawberries but is a needed tool as soon as possible.

Spinosad. This new active ingredient is not currently registered for use on strawberries but may be in the future.

CUTWORMS

Black Cutworm: *Agrotis ipsilon*

Roughskinned Cutworm: *Athetis mindara*

Damage. At times serious damage can occur to the plant crown. On fruit, during harvest, cutworms can cause pronounced holes. Early-season damage by newly hatched cutworms generally appears as small, webless perforations in the newly expanding crown leaves. As larvae grow, they begin their characteristic stem cutting along with chewing larger, irregular holes in the foliage. Damage by cutworms tends to be more serious in fields where bug-vacs have been used, but the reasons for this are not known and bug-vacs are rarely used.

Description of Pest. The black cutworm, also called the greasy cutworm, is the primary cutworm pest of strawberries in most growing areas but other species are found in damaging numbers on occasion. Most damage occurs in fall and spring, with the fall attack being more destructive. Migration of adult moths can also occur following harvest of other hosts, such as lettuce, in nearby fields.

Monitoring. Monitoring for cutworms is done visually or by trapping. Damage to fruit particularly is monitored.

CONTROLS

Cultural

Weed Control. Weed control is paramount to preventing a serious cutworm problem. Weedy fields tend to attract more moths to lay their eggs.

Vacuuming. This control is no longer used because vacuuming of small insects adversely impacts the control of cutworms (9).

Biological

Birds. Though birds can feed on cutworms and are the only known biological control, there is no evidence that this results in significant control and, of course, many of the same birds are serious pests to strawberries.

Chemical

Baits. Baits (primarily carbaryl bait) are applied as soon as evidence of substantial leaf and/or stem cutting is noted. Bait applications are also made immediately after weeding, when cutworms have been found in order to prevent migration to the crop plants. There is no specific threshold for treatment.

Carbaryl. 7 day PHI for bait. Carbaryl (SEVIN) is a broad-spectrum carbamate applied as a bait or a spray to strawberry beds around the base of the plants at an average rate of 1.6 lb ai/acre. It is most effective if applied at night when cutworms are more active. Carbaryl bait is very important for control of cutworm. Unlike carbaryl broadcast sprays, bait applications are not harsh to beneficials. Carbaryl is applied to approximately 25% of strawberry acres though this overall use is targeted towards several different including cutworms. The restricted-entry interval for carbaryl is 12 hours.

Bacillus thuringiensis. 0 days PHI. *Bacillus thuringiensis* (Bt) is applied at label rates to approximately 50% of strawberry acres. Good coverage at relatively low dilution rates is essential to product performance though this performance is typically quite low against cutworms. Multiple applications are required. Treatments are made when young larvae are present. Bt is acceptable for use on organically grown produce.

Chloropicrin. Chloropicrin as a pre-plant treatment, which is typically applied in combination with methyl bromide, can sometimes be effective in control of cutworms from previous crops. This combination of fumigants is used for preplant control of pathogenic fungi, weeds, nematodes, and soil borne insects, but can impact cutworm populations. The use of these chemicals in combination is being phased out. The use of chloropicrin alone may be effective against cutworms but may not be a common practice after the loss of methyl bromide.

Chlorpyrifos. 45 day PHI. Chlorpyrifos (LORSBAN) is a broad-spectrum insecticidal organophosphate that may be used for cutworm control. It is applied at an average rate of 1 lb ai/acre to approximately 15 % of strawberry fields though applications of this insecticide can be targeted for control of many pests, not just cutworm. Chlorpyrifos is an effective tool in the control of cutworm shortly after planting and is critical to production in southern

California, Santa Maria and Ventura County. It provides economic control but kills beneficial and nontarget organisms. The restricted-entry interval is 24 hours.

Methomyl. 7 day PHI for fresh and 10 day PHI for processing strawberries. Methomyl (LANNATE) is a carbamate that can be used to control cutworms when populations are anticipated to be high. Average applications are about 0.8 lb ai per acre with an average of 1 application per season. Methomyl was applied to about 25% of strawberry acreage in 1996. There is a 2 day restricted-entry interval for methomyl.

The following active ingredients are not currently registered for use on strawberries but are needed tools as soon as possible. Expedited registrations are encouraged by the industry.

Spinosad. This new active ingredient is not currently registered for use on strawberries but may be in the future.

Methoxyfenozide. This new insect growth regulator (INTREPID) is not currently registered for use on strawberries but could be an important tool for the strawberry industry.

Chlorfenapyr. Chlorfenapyr (ALERT) is not currently registered for use on strawberries but could be an important tool for the strawberry industry.

BEET ARMYWORM

Spodoptera exigua

Damage. The greatest damage from beet armyworm occurs to summer and fall-planted strawberries in the southern growing regions of the state. Newly hatched beet armyworms are foliage feeders, skeletonizing the upper or lower leaf surfaces adjacent to their egg mass. Larger larvae can attack the crowns of young plants, killing them. Young larvae feed on foliage before attacking berries. Larger armyworms feed directly into the berries. Smaller armyworms will often feed on the shoulder of the berry.

Description of Pest. Fall populations of armyworm moths will often fly into strawberry fields to lay eggs. Newly hatched armyworms are often green in color and feed in groups, skeletonizing the undersides of leaves.

Monitoring. Treatments are made while armyworms are still young. If large numbers of predators are present, treatments may be delayed to determine if the armyworms might be controlled by the natural enemies.

CONTROLS

Cultural

Weed Control. Growers control weeds in and near the field to minimize armyworm populations, as adult moths are attracted to weeds for egg laying.

Biological

***Hyposoter exiguae*.** Young beet armyworms can be heavily parasitized by the ichneumonid parasite, *Hyposoter exiguae*. This parasite is easily monitored in the armyworm populations by simply pulling young worms apart and looking for the parasite larva inside.

Natural Virus. Armyworms often become diseased with a virus that can cause high mortality. High natural mortality translates to few mature larvae surviving to cause further damage.

Chemical

***Bacillus Thuringiensis*, subsp. *aizawai*.** 0 day PHI. *Bacillus thuringiensis* (Bt) is applied at rates of 0.1 lb ai/acre and is the best subspecies for controlling beet armyworm. About 30% of the state's acreage is treated with Bt. Good coverage at relatively low dilution rates is essential to product performance. Bt treatments are made when armyworms are still small. For Bt to be effective it must be applied no later than the second instar. Bt is acceptable for use on organically grown produce. There is a 4 hour restricted-entry interval for Bt.

***Bacillus Thuringiensis*, subsp. *kurstaki*.** 0 day PHI. *Bacillus thuringiensis* (Bt) is applied at 0.1 lb ai/acre of strawberry. Bt applications are made onto about 30% of the state's acreage. Good coverage at relatively low dilution rates is essential to product performance. Treatments are made when armyworms are still small. To be effective it must be applied no later than the second instar. Bt is acceptable for use on organically grown produce. There is a 4 hour restricted-entry interval for Bt.

Methomyl. 3 day PHI for fresh strawberries. 10 day PHI for processing strawberries. Methomyl (LANNATE) is an oxime carbamate used to control armyworm when populations are high or when most of the larvae present are large. This insecticide can disrupt natural enemies of spider mites and other insects. The average application rate for methomyl is 0.8 lb ai per acre with typically one application being made per year even though multiple applications per season are allowed. Methomyl is applied to about 25% strawberry acreage. The restricted-entry interval for methomyl is 48 hours.

Pyrethroids. Synthetic pyrethroids (such as fenpropathrin and bifenthrin) can be used to control beet armyworms but these chemicals are harsh and impact beneficial organisms, often resulting in pest outbursts. These chemicals, if used, are used as cleanup.

The following active ingredients are not currently registered for use on strawberries but are needed tools as soon as possible. Expedited registrations are encouraged by the industry.

Spinosad. This new active ingredient is not currently registered for use on strawberries but may be in the future.

Methoxyfenozide. This new insect growth regulator (INTREPID) is not currently registered for use on strawberries but could be an important tool for the strawberry industry.

Chlorfenapyr. Chlorfenapyr (ALERT) is not currently registered for use on strawberries but could be an important tool for the strawberry industry.

WHITEFLIES

Iris Whitefly: *Aleyrodes spiroeoides*

Strawberry Whitefly: *Trialeurodes packard*

Greenhouse Whitefly: *Trialeurodes vaporariorum*

Damage. Whiteflies are always present in strawberry fields, but rarely build up to damaging numbers causing economic impact. Damage is typically limited to late season, sporadic outbreaks but their occurrence has become more widespread in the past few years for unknown reason. This is especially true of greenhouse whitefly. Like strawberry aphids, whiteflies suck plant juices and at high population levels can excrete large amounts of honeydew on which a sooty mold fungus grows. Whiteflies do not carry and transmit viruses of strawberry.

Description of Pest. Adult whiteflies are small insects. Whiteflies generally overwinter in the immature stage on the leaves of strawberries. Adults begin laying eggs on the undersides of leaves. Due to the relatively short life cycle of 4 to 5 weeks, there are several overlapping generations during the year.

Monitoring. Treatments are rarely necessary except along dusty road edges or if whitefly biological controls are disrupted by the use of a non-selective pesticide. Treatment is only necessary when honeydew becomes apparent, as has occurred more recently in the past few years.

CONTROL

Cultural

Topping. For summer-planted strawberries, the practice of topping in spring helps to reduce overwintering immature populations.

Dust Reduction. Growers minimize dust by keeping field roads watered or oiled allowing biological control to work effectively. Dust minimization helps in the control of mites and aphids also.

Vacuuming. The use of vacuuming small insects such as whiteflies is no longer practiced because the control was minimal and increases in secondary pests were aggravated (9).

Biological

Parasites and Predators. Numerous parasites and predators (e.g., *Prospetella*, *Encarsis*) generally hold down whitefly populations to the extent that damaging populations rarely occur. General predators include lacewings, bigeyed bugs (*Geocoris* spp.), and minute pirate bugs (*Anthocoris*). Use of harsh insecticides should be avoided where whitefly management is important.

Chemical

Imidacloprid. 14 day PHI. Imidacloprid (ADMIRE) can be used under an Emergency Registration (Section 18) in California. The ingredient is an effective agent against whiteflies and relatively non-disruptive of the biological balance that is important in control of whiteflies. However, moving the material onto plants from drip irrigation has proven to be problematic. The restricted-entry interval for imidacloprid is 12 hours.

Avermectin. 3 day PHI. Avermectin (a.k.a., abamectin)(AGRI-MEK) provides a fair control of whiteflies. It is applied at a average rate of 0.02 lb ai per acre to about 75% of strawberry acreage in California is treated with avermectin, with an average of 2 applications per field annually primarily for control of spider mites. Avermectin works poorly under cold weather conditions. A maximum of 4 applications is permitted in a growing season. Avermectin is not registered for use in strawberry nurseries. The restricted-entry interval for avermectin is 12 hours.

Insecticidal Soap. 0 day PHI. Insecticidal soap is occasionally used to control whitefly. Applications are made when it is cool to avoid burning plants and may be made once a month or twice per season.

Pyrethroids. Use of synthetic pyrethroids have been implicated as the cause of some whitefly infestations. However, in outbreak situations they also provide some control of whiteflies. They can be tank-mixed with other insecticides, such as diazinon, to improve efficacy.

The following active ingredients are not currently registered for strawberries but are needed tools as soon as possible. An expedited registration is encouraged by the industry.

Pyridaben. Pyridaben (PYRAMITE) is not currently registered for use on strawberries but it is needed as soon as possible for the control of whitefly. This is particularly relevant with the recent early season outbreaks of whiteflies in Ventura County and their widespread presence in the Santa Maria Valley, Monterey and Santa Cruz Counties. This material controls whiteflies without disrupting the beneficial organisms.

Pyriproxifen. Pyriproxifen (ESTEEM) is an insect growth regulator that is needed to complete the control program for whitefly.

SECONDARY INSECT PESTS

It is important to note that all discussions related to insect control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

CABBAGE LOOPER

Trichoplusia ni

Damage. Young cabbage looper larvae feed primarily on the undersides of leaves, skeletonizing them. High populations can damage fruit but this is very uncommon. The cabbage looper is becoming more a pest challenge in the southern growing regions.

Description of Pest. Loopers have a characteristic arch to their back as they crawl. Eggs are similar in appearance to corn earworm eggs, but flatter.

Monitoring. When monitoring for other pests, growers watch for evidence of looper feeding: leaflets with holes, feces, and caterpillars feeding at the edge of a hole. If larvae are larger instars, an organophosphate may be needed to control them.

CONTROLS

Cultural

Placement of Fields Relative to Other Crops. Cabbage looper has only recently become a pest in strawberries planted next to lettuce fields. Selecting a strawberry field that is not adjacent to a host crop for cabbage looper is one way to control infestations, although this practice has become less practical due to rotation with vegetable growers.

Biological

Parasitic Wasps. Loopers are sometimes controlled by the parasitic wasps *Hyposoter exiguae*, *Copidosoma truncatellum*, and *Trichogramma* spp.

Natural Virus. A natural outbreak of nuclear polyhedrosis virus also sometimes provides control of the looper population.

Chemical.

***Bacillus thuringiensis*.** 0 day PHI. *Bacillus thuringiensis* (Bt) is applied at label rates to approximately 0.1 lb ai/acre on to about 30% of the strawberry acreage. Applications are made when plants are dry, and good coverage at relatively low dilution rates is essential to product performance. Treatments are made when armyworms are still small. To be effective it must be applied no later than the second instar. Bt is acceptable for use on organically grown produce. The restricted-entry interval for Bt is 4 hours.

Diazinon. 5 days PHI. Diazinon is applied to strawberry fields at a rate of 0.8 lb ai/acre. Diazinon is not used unless loopers pose a serious threat to the crop. Diazinon is harmful to mite predators and outbreaks of twospotted spider mites may occur following its use. Diazinon is used to treat around 8% the state's strawberry acres. The restricted-entry interval for diazinon is 24 hours.

Chlorpyrifos. 21 day PHI. Chlorpyrifos (LORSBAN) is a broad-spectrum insecticide applied at an average rate of 1 lb ai/acre to approximately 15% of strawberry acreage. Applications are typically made pre-bloom. Chlorpyrifos provides economic control but kills beneficial and nontarget organisms. The restricted-entry interval for chlorpyrifos is 24 hours.

Methomyl. 3 day PHI for fresh and 10 day PHI for processing strawberries. Methomyl (LANNATE) is a carbamate that can be used to control cabbage looper and several other pests in strawberries. Average application rates are about 0.8 lb ai per acre, usually with a single application made per season. Methomyl was applied to about 25% of strawberry acreage in 1996. There is a 2 day restricted-entry interval for methomyl.

The following active ingredients are not currently registered for use on strawberries but are needed as soon as possible. Expedited registration is encouraged by the industry.

Spinosad. This new active ingredient is not currently registered for use on strawberries but may be in the future.

Methoxyfenozide. This new insect growth regulator (INTREPID) is not currently registered for use on strawberries but could be an important tool for the strawberry industry.

CORN EARWORM

A.k.a.: Tomato Fruitworm, Cotton Bollworm

Heliothis zea
Helicoverpa Zea

Damage. The south coastal zone is the only location where corn earworms can become a significant problem. Problems are most severe when the field is in close proximity to a corn or tomato field. Corn earworms damage strawberries by burrowing into fruit. Although there are several generations each season, only larvae of the first generation attack winter strawberries. Entrance holes made by early instar larvae are not visible, and the fruit must be cut to determine their presence. Contamination of the fruit prevents it from being marketed as whole fruit. Federal tolerance currently requires downgrading to juice stock if a single 7 mm or larger larva is found per 44 pounds of fruit (about 1,100 berries).

Description of Pest. Adult corn earworms are light grayish brown moths. Larvae typically feed within the fruit. Mature fruit containing large larvae appear seedy and develop a shrunk surface with one or more brown patches. The time needed to complete a generation is temperature dependent, but often takes about 1 month.

Monitoring. Growers monitor yearly for corn earworm in the south coast region using pheromone traps. Pheromone traps help monitor emergence and flight activity of the moths in late February/early March. When unparasitized eggs are found in the strawberry field, growers consider chemical treatments. Outbreaks of corn earworms often occur in years when warm air currents associated with El Niño conditions allow moths to migrate from the south. Monitoring is increased under these conditions.

CONTROLS

Cultural

Corn Grow in Close Proximity. Growers have planted a very early maturing sweet corn cultivar around strawberry fields to provide an alternate, and more attractive host plant for the corn earworm in an effort to reduce the impact of this pest on strawberries. The theory was that female moths strongly prefer corn to lay their eggs and will leave strawberries alone if corn or other preferred hosts are available to them. However, the use of a corn as an alternate host or a windbreak in close proximity with strawberries can also enhance corn earworm populations and infestations on strawberries, so this cultural control concept may not be viable for many growers.

Biological

General Predators. A number of predaceous insects and parasites will feed on corn earworm eggs. A tiny parasitic wasp, *Trichogramma pretiosum*, has been found developing in *Helicoverpa* eggs on strawberries, but the percent parasitization from natural populations appears to be low. *Trichogramma* can be purchased from commercial sources for augmentative release. The minute pirate bug is a predator that has been observed to feed on corn earworm eggs. While both of these biocontrol agents can provide some pest suppression, the very low tolerance for insect contamination in strawberries makes this control option less effective when populations are high.

Chemical

Methomyl. 3 day PHI for fresh strawberries and 10 day PHI for processing strawberries. Methomyl (LANNATE) is an oxime carbamate. Typically, 0.8 lb ai/acre applied with a single application per year though multiple applications are allowed. Methomyl is applied on about 25% of the strawberry acreage. Use of methomyl often results in mite problems. There is a 2 day restricted-entry interval for methomyl.

Bacillus thuringiensis. 0 day PHI. *Bacillus thuringiensis* (Bt) is most effective against newly hatched larvae and not very effective against large larvae and those that have already entered the fruit to feed. Treatments must be carefully timed to egg hatch. Because residual activity is short, repeat applications at 4- to 7-day intervals is often necessary during extended periods of peak egg hatch. Bt is applied at label rates to approximately 30% of treated strawberry acres. Bt is acceptable for use on organically grown produce. The restricted-entry interval for Bt is 4 hours.

Chlorpyrifos. 45 day PHI. Chlorpyrifos (LORSBAN) is a broad spectrum organophosphate applied at an average of 1 lb ai per acre to approximately 15% of strawberry acreage. Chlorpyrifos is an effective tool in the control of corn earworm. Provides economic control but kills beneficial and nontarget organisms. There is a 24 hour restricted-entry interval for chlorpyrifos.

EUROPEAN EARWIG

Forficula auricularia

Damage. Earwigs are a pest of the south coast region. Earwig feeding results in small deep holes in the fruit that can only be distinguished from slug damage by the absence of slime.

Description of Pest. Earwigs feed at night and can be found hidden around crowns of plants during the day. They are slender brown insects, about 0.5 to 0.75 inch long. They have a conspicuous pair of pincers attached to back end of the abdomen. The pest becomes most destructive as nymphs approach maturity from April to July.

Monitoring. When significant fruit splitting occurs, applications of bait are needed if earwigs are present

CONTROLS

Cultural

Sanitation. Field sanitation is important in the control of earwigs. Rubbish near strawberry fields should be destroyed or removed.

Biological

No significant biological controls are known.

Chemical

Carbaryl. 7 day PHI for bait. Carbaryl (SEVIN) bait is a carbamate bait that can be applied to strawberry beds around the base of the plants at a rate of 1.6 lb ai/acre. Carbaryl is applied to approximately 24% of treated strawberry acres though these applications are made to control several insect pests. The restricted-entry interval is 12 hours.

HOPLIA BEETLE WHITE GRUBS *Hoplia oregona*

Damage. Hoplia larvae, or white grubs, typically feed on perennial grasses but may attack strawberries feeding on the roots of strawberry plants. Small rootlets may be devoured and the bark and cortex of larger roots destroyed. Injured plants wilt as the roots can no longer provide moisture from leaves. Hoplia may be found throughout California but is most frequently found in the Central Valley. Damage is rarely seen in fumigated fields. Hoplia larvae has become a serious pest in nonfumigated fields in the Central Valley, where it has killed half the plants in heavily infested fields.

Description of Pest. Adults are brown beetles that are active for about two weeks after emerging in May, feeding on plants, mating and laying eggs on the soil. Adults are inconspicuous because they fly poorly. *Hoplia* larvae are white grubs that feed on plant roots for up to two years before pupating. Soil fumigation has kept white grubs from becoming a problem.

Monitoring. Growers monitor the fields for evidence of beetles or damage from larvae. Injured plants often develop in a small circular area. Though some damage is acceptable, severe damage triggers control methods.

CONTROLS

Cultural

Crop Rotation. Annual plantings reduce the likelihood of high populations building in fields. Crop rotation with non-host cover or cash crops may also help reduce infestations.

Weed-Host Control. Control of host plants adjacent to fields helps to reduce the potential for infestation.

Biological

No known biological controls of *hoplia* larvae.

Chemical

Soil Fumigation - General. Soil fumigation with methyl bromide and chloropicrin for weed and disease control has greatly reduced the presence and effect of *Hoplia* beetle and white grubs. Currently, *Hoplia* beetles rarely require management due preplant fumigation. However, with the impending loss of methyl bromide as a soil fumigant, it may be anticipated that *Hoplia* beetle management throughout the growing regions will increase.

Methyl Bromide with Chloropierin. 0 day PHI. Methyl Bromide with chloropicrin is applied as a preplant application, approximately 30 days prior to planting, to fields at a rate of 300 to 400 lbs ai combination/acre. It is applied to essentially all of the conventionally grown strawberry fields in California for control of pathogenic fungi, weeds, and nematodes. Methyl bromide is a restricted use material that may only be applied by permit from the county agricultural commissioner. Many use restrictions apply. The restricted entry interval for methyl bromide is 48 hours.

GARDEN SYMPHYLAN

Scutigerella immaculata

Damage. Garden symphylans damage plants by feeding on roots, thus retarding plant growth. They are usually only a problem in fields that were not fumigated, or if the fumigation was ineffective.

Description of Pest. Garden symphylans are slender and white. They occur mainly in moist soils with good structure and a high organic matter content, and are often associated with debris from a previous crop that is not completely decomposed. Since these pests rarely leave the vicinity of their infestation, they return to damage the same area every season so infestations spread slowly.

CONTROLS

Cultural

Flooding. Continuous flooding for 3 weeks in the summer helps reduce infestations though this practice is not feasible.

Crop Rotation. Growers sometimes grow and disc in a cover crop of sorghum to reduce infestations in other crops.

Biological

There are no known biological controls that specifically target the garden symphylan.

Chemical

Soil fumigation, with methyl bromide and chloropicrin, for weed and disease control also controls garden symphylans. None of the registered insecticides will control this pest.

Methyl Bromide and Chloropicrin. This combination of fumigants, when used preplant to control weeds, nematodes and other pests, also controls garden symphylans. Methyl bromide is being phased out so this sole chemical pest management tool will not be available and alternate controls are not available. Infestations by symphylans could become worse in future years as a result of this transition.

GARDEN TORTRIX

Ptycholoma (Clepsis) peritana

Damage. Contamination of south coast fields just before the berries are sent to the processors during late June and July can be a serious problem. Garden tortrix larvae generally feed on dead and decaying leaves and fruit usually causing no significant damage. However, as the population increases and the plant canopies close in, more ripening berries settle down into the trash among the tortrix larvae. When this happens, larvae will often spin a nest in creases along the berry's surface and chew small, shallow holes in the berry, incidental to their scavenging. With the higher populations often attained by late spring or early summer, significant fruit losses can result from both larval contamination and secondary rots invading the feeding holes.

Description of Pest. The adult has the typical bell-shaped tortricid moth wings while at rest. Adults aren't usually seen until March or April. Larvae hatching from eggs laid in spring on older leaves move down into the trash where they feed on dead and decaying leaves. They construct shelters by tying bits of trash together. As a result of overlapping generations, all stages are generally present in spring and summer.

Monitoring. Late May, June, and early July are generally when treatments may be required. Chemical control is difficult to achieve due to the location of the larvae down in the litter beneath the protective canopy of strawberry leaves.

CONTROL

Cultural

Trash Removal. This is the most important control method since the populations build up on dead leaves. When populations can no longer be supported on dead material, they go onto live plants. In areas with a chronic tortrix problem, growers remove accumulated trash around the plants in spring with either blowers or suction devices to limit the potential for a large population buildup. In severe situations, extra help may be required to sort out contaminated or damaged berries during harvest.

Biological

There are no known biological controls that specifically target garden tortrix.

Chemical

***Bacillus thuringiensis*, subsp. *kurstaki*.** 0 day PHI. *Bacillus thuringiensis* (Bt) is applied at label rates to approximately 30% of treated strawberry acres. Bt is acceptable for use on organically grown produce. The restricted reentry interval is 4 hours.

SALTMARSH CATERPILLAR

Estigmene acrea

Damage. Saltmarsh caterpillar is occasionally a pest in the Fall in southern growing regions when hot temperatures prevail. When saltmarsh caterpillars first hatch, they remain clustered and feed on the undersides of the leaves where the egg mass was laid. They skeletonize the foliage. As caterpillars grow, they eat holes in the leaves. This type of damage is generally of little or no concern, but the caterpillars can also make superficial bites in the fruit, causing significant economic loss.

Description of Pest. Adult moths are white with orange abdomens. Mature caterpillars are almost 2 inches long. Emerging moths lay their round, shiny eggs in several rows forming a neat cluster on the undersides of leaves. There are several generations each year.

CONTROLS

Cultural

Barriers. Caterpillars migrating from adjacent fields or uncultivated areas can be stopped by a physical barrier such as a plowed ditch, a ditch of water, or a slippery, vertical aluminum foil fence several inches tall.

Biological

Natural Predators. Young larvae have a high mortality rate, perhaps from a naturally occurring virus, which helps to limit populations. There are also a number of natural enemies, including parasitic wasps and flies that help to control this pest.

Chemical

***Bacillus thuringiensis*.** 0 day PHI. *Bacillus thuringiensis* (Bt) sprays are best applied when the young caterpillars are still in the gregarious, skeletonizing phase. Bt is applied at label rates to approximately 30% of the strawberry acres. Good coverage at relatively low dilution

rates is essential to product performance. Bt is acceptable for use on organically grown produce. The restricted-entry interval for Bt is 4 hours.

VINEGAR FLY

Drosophila melanogaster and other species

Damage. Vinegar flies (a.k.a., fruit fly) are primarily a problem in strawberries picked for processing. In general, the vinegar fly can be a problem from the Oxnard Plain south. Because this fruit is allowed to ripen in the field to allow easy removal of the calyx and core of the strawberry during picking, the harvest interval is increased and the fruit becomes more susceptible to infestation. Vinegar flies are attracted to very ripe or damaged fruit in the field where they lay their eggs. Eggs and larvae are primarily a contamination problem.

Description of Pest. Vinegar flies, also known as fruit or pomace flies, are small, yellowish flies. This pest has become more important in recent years with an increasing need for alternative control methods.

Monitoring. No monitoring or treatment guidelines exist for vinegar flies in strawberries, although yellow sticky cards are sometimes used to monitor adult fly populations. Adults and their offspring may be monitored with fermented fruit traps consisting of a container filled with overripe fruit covered with an inverted funnel.

CONTROLS

Cultural

Removal of Ripe Fruit. Growers limit breeding sites for fruit flies by making certain that ripe fruit are completely removed from the plants. When possible, harvest intervals are shortened as temperatures increase.

Sanitization. Good sanitation is practiced in and around the field with growers cleaning up external sources of flies such as cull piles of strawberries or other rotting fruit in nearby acreage, such as citrus groves, where old fruit may be on the ground. This practice is rarely performed due to labor costs and worker shortages.

Biological

There are no known biological controls that specifically target vinegar flies.

Chemical

Vinegar fly eggs and larvae in the berries cannot be killed using insecticides. Treatments are applied to kill adult flies.

Naled. 1 day PHI. Naled (DIBROM) is the most common treatment for vinegar flies. It is an organophosphate that is applied at rates of about 1 lb ai per acre. It was applied to about 18% of the state's acreage. When used naled is typically applied once a year. Naled provides good late season control but is not used when temperatures exceed 85°F due to phytotoxicity. Use is typically limited to regions where the end of the season is cool. The restricted-entry interval for naled is 24 hours.

Malathion. 3 day PHI. Malathion provides effective control of vinegar flies. Malathion is applied at an average rate of 2 lb ai/acre to 55% of strawberry acreage. The restricted-entry interval for malathion is 12 hours.

Methomyl. 3 day PHI for fresh strawberries and 10 day PHI for processing strawberries. Methomyl (LANNATE) may be applied at a rate of about 0.8 lb ai/acre. Methomyl is applied to 25% of strawberry acreage. The restricted-entry interval for methomyl is 48 hours.

Diazinon. 5 day PHI. Diazinon is applied to strawberry fields at an average rate of about 0.8 lb ai per acre with an average of 1 application per year. Diazinon is used to treat about 8% of strawberry acres. The restricted-entry interval for diazinon is 24 hours.

Pyrethrin. 0 day PHI. Pyrethrin is applied at 0.03 lb ai per acre to approximately 6% of treated strawberry acreage. Pyrethrins are less effective and more costly than other products and are not the first choice tool for control. Use of pyrethrins requires multiple treatments to obtain control. There is a 12 hour restricted-entry interval for pyrethrin.

Azinphos Methyl. 7 day PHI. Azinphos methyl (GUTHION) applications are rarely used against vinegar flies because the pre-harvest interval is relatively long and the reentry intervals are even longer (most greater than 30 days).

NEMATODE PESTS

It is important to note that all discussion related to nematode control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

FOLIAR NEMATODE

Aphelenchoides fragariae

NORTHERN ROOT KNOT NEMATODE

Meloidogyne hapla

Symptoms and Damage. The presence of either foliar or northern root knot nematodes may result in plant stress and reductions in yield. Under current practices of fumigating strawberry fields with methyl bromide and chloropicrin and using certified nursery stock, these nematodes are rarely found to cause significant damage in California production areas. However, with the impending loss of methyl bromide and the increasing use of organic methods damage will likely become more common. Control of these two pests by nursery stock producers is critical because an infestation will prevent the grower from receiving government certification, thereby reducing the value of the planting stock.

Plant symptoms can be indicative of a nematode problem but are not fully diagnostic because similar symptoms could result from other problems as well. The symptoms may either be widespread or may appear in small patches within a field. Aboveground symptoms of foliar nematode include stunted growth, reddened leaves, small curled or crinkled leaves (crimp), deformed buds and flowers, and a reduction in flowering and fruiting. A reduction in flowering and fruiting may more reliably distinguish a foliar nematode infestation from insect infestations, which produce leaf symptoms similar to those described above. There are no reported below-ground symptoms with foliar nematodes. Aboveground symptoms of root knot nematodes include wilting during hot days, stunting, chlorosis, and suppression of fruit yields. Root galls formed near the root tips and abundant branching at and above the galls are the primary belowground symptoms of this pest.

Description of Pest. Plant parasitic nematodes are microscopic, unsegmented roundworms. The two species most commonly associated with damage in California strawberries are the foliar nematode, *Aphelenchoides fragariae*, and the northern root knot nematode, *Meloidogyne hapla*. Strawberries are also hosts for the following nematodes: root lesion (*Pratylenchus penetrans*), stem (*Ditylenchus dipsaci*), dagger (*Xiphinema americanum*), needle (*Longidorus elongatus*),

foliar (*Aphelenchoides ritzemabosi*, *Aphelenchoides besseyi*), and root knot (*Meloidogyne incognita* and *Meloidogyne javanica*). All of these nematodes are potential pathogens to strawberries in California and their identification in strawberry plantings or in land to be planted to strawberries are cause for concern.

Monitoring. To make management decisions, a grower must monitor the field by taking soil and plant samples, sending them to a diagnostic laboratory for identification. Sampling and extraction techniques are typically 30 to 50% effective in detecting species that might be present.

CONTROLS

Cultural

Limitations on Transfer of Pest. The selection of planting site, non-infested planting stock, cleaning of equipment to minimize nematode transfer, avoidance of nematode-infested irrigation water, hot water treatments of planting stock, and crop rotations are cultural techniques used by growers to control nematode infestations.

Solarization. There has been some experimentation where solar energy has been used to help suppress nematode populations. It is not yet clear whether this technique can be a feasible alternative within an IPM program.

Biological

There are no known biological control agents that have been shown to control or suppress nematodes.

Chemical

Methyl Bromide. Methyl Bromide is applied as a preplant application to fields at a combined rate, with chloropicrin, of 300 to 400 lbs/acre. It is typically applied in combination to essentially all of the state's acreage to provide control of pathogenic fungi, weeds, and nematodes. When used properly, methyl bromide provides excellent preplant control of root-infesting plant parasitic nematodes. Methyl bromide is a restricted use material that may only be applied by permit from the county agricultural commissioner. Methyl bromide is being phased out with interim reductions and will not be available for use starting 2006. The restricted-entry interval for methyl bromide is 48 hours.

Metam Sodium. Metam sodium is applied as a preplant fumigant to less than 1% of strawberry fields. Metam-sodium is a preplant material for nematode control provided it gets to the target organism. If used properly, it can provide some nematode control in

many situations, but it has a reputation of being consistent but relatively ineffective with regard to this control. These problems are due largely to nonuniformity of application as a result of land preparation and insufficient water for movement resulting in subsequent failure of the material to contact and kill the nematodes present. The restricted-entry interval for metam sodium is 48 hours.

Oxamyl. Oxamyl is only registered for use on root knot (except Javanese), sting, burrowing, and root lesion nematodes on nonbearing nursery stock that will not bear fruit within 12 months after application. Some cultivars have exhibited phytotoxic symptoms; therefore, oxamyl is typically used on a small scale to determine crop sensitivity prior to large scale field application.

Chloropicrin. Chloropicrin is typically applied in combination with methyl bromide for the control of pathogenic fungi, weeds, and nematodes. Efficacy data for chloropicrin alone is poor for nematode control on strawberries and is typically not used alone. Use of chloropicrin, alone, is not permitted in San Diego County.

PRIMARY DISEASES

It is important to note that all discussion related to disease control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

BOTRYTIS FRUIT ROT

Botrytis cinerea

Damage. Botrytis Fruit Rot or Gray Mold is the most common and most serious disease of strawberry fruit in California. This disease can affect all parts of the plant. Both fruit and nursery production are impacted. It is estimated that botrytis damage can reduce the value of California's harvest by 30 to 40% compared to production where chemical methods of pest management are not practiced (8). This loss can be as high as 50% to 60% under conditions of severe disease challenge and when infestation in the field reaches this level the economic loss is 100%. Botrytis fruit rot occurs in all growing areas and can cause losses of fruit both in the field and after harvest. Infected berries maintain their original shape and take on a velvety grey brown coat of mycelium and spores. Initially, rotted areas are soft and mushy, becoming leathery and dry in the absence of high humidity. Direct infection of the berries also occurs if berries are exposed to free water. These infections develop in the same manner as flower-infected berries, but differ in that multiple initial lesions may appear anywhere on the berry's surface. For nurseries, damage to petiole and leaf tissue can be significant.

Description of Disease. Botrytis fruit rot is widespread. It can infect flowers on strawberry plants when spores landing on them are exposed to free water and cool temperatures. Infections can either cause flowers to rot or Botrytis can become latent. Latent infections resume activity on the berry later in the season. Both green and red berries are susceptible, but ripening berries rot faster. During the growing season, the fungus is constantly present.

Monitoring. Inoculum density and environmental conditions conducive to disease development (i.e., rain and cool temperatures) determine when fungicide applications are needed. Because these conditions are usually seasonal, a protective application of a fungicide is used typically to prevent germination of spores when conditions are ideal for disease development. Spray schedules thereafter are set according to disease pressure and environmental conditions.

CONTROLS

Control of Botrytis fruit rot ranges from repetitive fungicide treatments with no cultural control to intensive cultural methods with limited or no fungicide applications. Environmental conditions in various microclimates play an important role in determining control strategies. It is crucial to avoid or delay the onset of fungicide resistance. It is common practice to rotate the use of fungicides between chemicals that represent different chemical classes.

Cultural

Removal of Infected Material. Nothing can be done to escape the presence of this fungus, but the level of inoculum in a particular field can be reduced by removing dead leaves and infected fruit. Removal and destruction of dead or infected plant material reduces the amount of inoculum capable of producing new infections.

Canopy Size. The spacing between rows is an important consideration in mitigating the severity of Botrytis fruit rot. Wider spacing allows for greater “breathing” room, conditions that do not favor botrytis infestation. In addition, the management of plant (canopy) size can similarly open up the space between plants, allowing “breathing” room and air circulation.

Barriers/Mulches. Use of plastic mulches prevents berry-soil contact, thus reducing disease. For organic growers, it is important to select growing areas that have environmental conditions that are not conducive to disease development. Mulches that provide optimum air circulation may also help in controlling the disease.

Fertilizers. Excess fertilizer use, particularly too much nitrate fertilization, may enhance botrytis fruit rot development and result in adverse production and quality impacts. These impacts may be due to the effects on fruit integrity and strength.

Biological

No biological control agents are currently available to the industry that target botrytis fruit rot. *Trichoderma harzian* is being developed as a possible biological control agent (to be registered under FIFRA) but has not been commercialized yet.

Chemical

It is crucial to avoid or delay the onset of fungicide resistance. As a result, fungicide applications are usually rotated through several active ingredients during a season, with fungicides of different chemical classes being applied in sequence. Use of repeated

applications of the same or related fungicide is avoided. Due to the differences in price of the available fungicides, this approach can be financially challenging. Tank mixing of fungicides is also common, lowering the application rate required of any single fungicide.

Iprodione. 0 day PHI. Iprodione (ROVRAL) is a dicarboximide fungicide applied at an average rate of about 1 lb ai per acre to over 70% of strawberry acreage. Iprodione is an important tool in the control of botrytis in the south coast area; however, new label restrictions in 1999 limit applications to pre-bloom, thus eliminating iprodione as a fungicide resistance management tool. The restricted-entry interval for iprodione is 12 hours.

Captan. 0 day PHI. Captan is a N-trihalomethylthio fungicide that provides good control of Botrytis in the coastal areas and is applied at 2 lb ai/acre to over 90% of strawberry acreage. It is applied anywhere from 1 to 12 times per season, with 3 applications per season being the average statewide (multiple applications per field are usually made at reduced rates in tank mixes with other fungicides). Under severe disease pressure, captan is used every 5-7 days. It is not applied in combination with or immediately following application of spray oils. The restricted-entry interval is 1 day for captan.

Vinclozolin. 0 day PHI. Vinclozolin (RONILAN), a dichloroanilide fungicide, is applied at an average rate of 1 lb ai per acre to greater than 30% of strawberry acreage. Registration of this product was cancelled in 1999 therefore vinclozolin will no longer be available for use on strawberries. The restricted-entry interval for vinclozolin is 12 hours.

Thiram. 3 day PHI. Thiram is a dithiocarbamate applied at an average rate of 2 lb ai/acre to about 60% of strawberry acreage. The average number of annual applications of thiram on a field is 2. Use of thiram can result in white residues, making late season applications of this ingredient less common. It is not applied in combination with or immediately following application of spray oils. The restricted-entry interval is 1 day for thiram.

Benomyl. 1 day PHI. Benomyl (BENLATE) is a carbamate applied at an average rate of 0.5 lb ai/acre to about 40% of the strawberry acreage. The label for benomyl requires its use in combination with other fungicides (e.g. captan, thiram). Resistance to benomyl is at very high levels and has been identified in all strawberry growing regions. To reduce the likelihood of resistance development, applications are typically alternated with products of different chemistry (e.g., captan, fenhexamid, or thiram). The average number of applications of benomyl per field per year is 1. A total of 5 lbs ai per acre per year is allowed. The restricted-entry interval for benomyl is 24 hours.

Thiophanate-Methyl. 1 day PHI. Thiophanate-methyl (TOPSIN) is applied at an average rate of 0.7 lb ai/acre. It is only used on 4% of the strawberry acreage with one application per year being the average. It is usually used in combination with a fungicide of a different chemistry class (such as captan or thiram) to reduce resistance problems. The restricted-entry interval for thiophanate-methyl is 12 hours.

Fenhexamid. 0 day PHI. Fenhexamid (ELEVATE) is a new active ingredient, first registered in 1999. It is in a new chemical class and has been classified as a reduced-risk pesticide by the USEPA. There is no use data on this product yet but it is anticipated to be widely used in its first year (greater than 50% of the strawberry acreage). The restricted-entry interval period is 4 hours.

The following active ingredients are not currently registered but are needed as tools as soon as possible. An expedited registration is encouraged by the industry.

Chitosan. This new active ingredient is a biochemical that is anticipated to be registered in California in 2000. Chitosan (ELEXA) is effective on powdery mildew and provides suppression of botrytis. The PHI is 0 days and the restricted-entry interval will be 4 hours.

Cyprodinil With Fludioxonil. The combination of cyprodinil and fludioxonil (SWITCH) is available as a Section 18 for Strawberries in southeastern United States. This reduced risk combination is needed now for disease control and to manage fungicide resistance.

VERTICILLIUM WILT

Verticillium dahliae

Damage. *Verticillium wilt* is becoming an increasingly important disease in California strawberries. It is slow growing but, once established, it is extremely difficult to eradicate. Spread of the disease from contaminated planting stock is an increasing concern, making control of this disease at the nursery stage crucial. The pathogen is a soil-borne fungus and the loss of the methyl bromide/chloropicrin combination fumigant is anticipated to have a significant adverse effect by increasing the prevalence of *Verticillium wilt*. *Verticillium wilt* causes outer leaves to exhibit marginal and interveinal browning, followed by eventual collapse. Inner leaves remain green but are stunted and exhibit brownish black streaks or blotches. This last symptom distinguishes this disease from crown rot. Outbreaks of the disease typically result in observable “streaks” or “stripes” within the field.

Description of Disease. The fungus is not host specific and infects many weed species and crops worldwide. It is especially destructive in semi-arid areas where soils are irrigated. Inoculum densities may be high following planting of susceptible crops. Disease severity is greater when excessive levels of nitrogen are used.

Monitoring. The most common indication of Verticillium wilt is the observation of brown or dead outer leaves with green inner leaves.

CONTROL

Cultural

Fertilizer Limitation. High nitrogen fertilizers are avoided since the disease severity is greater when levels of soil nitrogen are excessive.

Crop Rotation. Growers with infested fields can rotate the fields to crops that are less susceptible to verticillium wilt. However, Verticillium infects a wide variety of crops and relatively few rotational crop choices are viable. Also, Verticillium wilt (microsclerotia) may remain viable in soil for up to 20 years suggesting that a rotation cycle of 20 years or more is necessary.

Irrigation Control. Use of drip irrigation and other irrigation practices that limit spread of this soil-borne disease can be helpful.

Fertilizer Limitation. High nitrogen fertilizers are avoided since the disease severity is greater when high levels of soil nitrogen are present.

Field Selection. Selection of fields that are free of the disease is an important factor. In particular, organic growers try to select fields isolated from conventional growing areas, when possible.

Resistant Cultivars. Growers can use less susceptible cultivars when practical, though resistance to Verticillium wilt is rarely an important criteria selection of current commercial varieties. However, all current California varieties are susceptible to Verticillium wilt in comparison to other crop hosts.

Chemical

Chloropicrin. Though currently applied in combination with methyl bromide, chloropicrin is the more effective of the two fumigants against Verticillium wilt. When used alone chloropicrin at rates of less than 200 lb ai per acre are not sufficiently effective. If Verticillium wilt is an important concern in the treated field, the proportion

of chloropicrin to methyl bromide is increased. Chloropicrin is more effective for Verticillium wilt when used in combination with methyl bromide than when used alone. Chloropicrin is currently applied to almost all the strawberry acreage in California in combination with methyl bromide. San Diego County does not permit the use of chloropicrin alone. There are numerous restrictions on the application of this restricted-use pesticide.

Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant application to fields at a combined rate of 300 to 400 lbs/acre. It is currently applied to essentially all of the commercial acreage, both production and nursery, in California. Since chloropicrin is the more effective of these two chemicals against Verticillium wilt, the relative proportion of chloropicrin is increased in fields where the control of this disease is important. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Metam Sodium. Metam sodium is applied at a preplant soil drench to less than 1% of treated fields. Metam-sodium can be a marginally effective preplant material provided it gets to the target organism. Metam sodium delays growth of Verticillium but does not get down deep enough in the soil to effectively control the disease. The restricted-entry interval for metam sodium is 48 hours.

RHIZOPUS FRUIT ROT

Rhizopus spp.

Damage. The fungus lives on and helps break down decaying organic matter. It invades strawberries through wounds and secretes enzymes that degrade and kill the tissue. Under conditions of high relative humidity, the berry rapidly becomes covered with a coat of white mycelium and spores. After high temperatures, the disease can become quite destructive. Outbreaks of the disease have caused 20 to 35% loss in production in the Oxnard plain.

Description of Disease. Initial infections appear as discolored, water-soaked spots on fruit. These lesions enlarge rapidly, releasing enzymes that leave the berry limp, brown, and leaky. The sporangiophores develop black sporangia, each containing thousands of spores. When disrupted, these sporulating berries release a cloud containing millions of sporangiospores.

Monitoring. Observations of twig die-back indicates presence of the disease.

CONTROLS

Cultural

Sanitation. Field sanitation also is extremely important: growers do not leave discarded plant refuse or berries in the furrows, and remove all ripe fruit from the field.

Post-Harvest Cooling. *Rhizopus* stops growing at temperatures around 46 to 50°F (8 to 10°C), so rapid postharvest cooling of fruit is essential for disease control.

Varietal Effects. Growers select cultivars with thick cuticles that are less susceptible to *Rhizopus* Fruit Rot in diseased areas because they are better able to resist infection.

Biological

There are no biological control techniques specific to *Rhizopus* Fruit Rot at this time.

Chemical

There are no chemical treatments that are highly effective against *Rhizopus* Fruit Rot but the following chemicals can be used.

Thiram. 3 day PHI. Thiram is a dithiocarbamate applied at an average rate of 2 lb ai/acre to about 60% of strawberry acreage. Again, the primary target of these applications is the control of Botrytis, not *Rhizopus*. Applications against *Rhizopus* are made only during outbreaks of the disease. The average number of annual applications of thiram on a field is 2. Use of thiram can result in white residues, making late season applications of this ingredient less common. It is not applied in combination with or immediately following application of spray oils. The restricted-entry interval for thiram is 1 day.

Captan. 0 day PHI. Captan is a N-trihalomethylthio fungicide that provides good control of *Rhizopus* and is applied at 2 lb ai/acre to over 90% of strawberry acreage. It is applied anywhere from 1 to 12 times per season, with 3 applications per season being the average statewide (multiple applications per field are usually made at reduced rates in tank mixes with other fungicides). Under severe disease pressure, captan is used every 5-7 days. It is not applied in combination with or immediately following application of spray oils. The restricted-entry interval is 1 day for captan.

POWDERY MILDEW

Sphaerotheca macularis

Damage. Powdery mildew is mostly limited to the coastal growing regions and northern nurseries, and causes very little damage in inland growing regions. Infestations during the 1990s have been the worst in the central coastal region. Some of the differences in vulnerability are due to the different varieties that are grown in these different regions. Infected flowers produce deformed fruit or no fruit at all. Severely infected flowers may be completely covered by mycelium and killed. Infected immature fruits become hardened and desiccated, often resulting in the observation of fruit “bronzing”. Infected leaves initially produce small, white powdery colonies on the undersides of leaves.

Description of Disease. Colonies of powdery mildew multiply to cover the entire lower leaf surface, causing the edges of the leaves to roll up. Purple-reddish blotches appear on the upper and lower surface of leaves. Infected mature fruits become seedy in appearance and support spore-producing colonies that look powdery and white. The disease overwinters as mycelium on leaves in California, so it is most likely introduced into the field through planting material or spores from neighboring fields. Ideal conditions for infection are dry leaf surfaces, high relative humidity, and cool to warm temperatures. Because of this, the disease is mostly limited to the coastal growing regions and northern nurseries, and causes very little damage in inland growing regions.

Monitoring. Early signs of the disease are monitored since preventative control is most effective. Applications are often tied to models based on meteorological observations.

CONTROL

Cultural

Resistant Cultivars. Growers use resistant cultivars where practical. Use of these varieties is typically region dependent with few of the varieties used in the central coast region being resistant to powdery mildew. Statewide, the most common varieties used in production are all relatively susceptible to powdery mildew.

Overhead Irrigation. Overhead irrigation is avoided as it enhances the onset and severity of the disease.

Biological

***Ampelomyces quisqualis*.** 0 day PHI. *Ampelomyces quisqualis* (AQ10) is a biofungicide which is a selective fungal hyperparasite. Use rates are from 0.5 - 1.0 oz/acre. This product works well early in the season but is less effective in inland growing regions. It is also incompatible with other fungicides so its use is usually limited to the early season in coastal growing regions. Because this biological control is registered under FIFRA as a pesticide, it is also listed below under Chemical controls for powdery mildew. The restricted-entry interval is 4 hours.

Chemical

Controlling the disease on leaves with fungicides does increase yields, though losses are almost entirely due to infection of flowers and fruit. Flower and fruit infections generally are the result of severe leaf infections. Protective fungicides are used to protect flowers and fruit. Fungicides are applied about 1 month after planting and again 3 to 4 weeks later. Additional treatments are made when plants begin to bloom.

Myclobutanil. 3 day PHI. Myclobutanil (RALLY) is an azole fungicide applied at a rate of 0.1 lb ai/acre and offers good long-term control. It is applied to approximately 65% of strawberry acres. The average number of applications per year is 2 though up to 6 applications per year are allowed. It is applied by permit from a county agricultural commissioner under a Section 18 registration that has been ongoing for several years. The restricted-entry interval for myclobutanil is 48 hours.

Micronized Sulfur. 0 day PHI. Micronized sulfur is applied at rates averaging 3.75 lb ai/acre and requires multiple treatments for control (the average number of annual applications is 3). Sulfur should be applied in cooler climates as applications during high temperatures may be phytotoxic to plants burning the foliage. It should also not be applied within 3 weeks of an oil application. Sulfur is applied to about 70% of strawberry acreage. Application rates are significantly higher (typically 10-fold higher) for organic growers, where alternate products are not available or effective, particularly late season. The restricted-entry interval is 24 hours.

Benomyl. 1 day PHI. Benomyl (BENLATE) is a carbamate applied at rates of 0.5 lb ai/acre onto about 40% of the strawberry acreage. Rarely used alone, benomyl is typically used in combination with captan or other fungicides. A total of 5 lbs ai per acre per year is the maximum rate allowed. The restricted reentry period is 4 hours.

Insecticidal Soap. 0 day PHI. Insecticidal soap is applied at rates of 5.5 lb ai/acre. It is not used on new transplants, un-rooted cuttings, or water-stressed plants and should not be applied when leaf temperature exceeds 90°F. These soaps can be phytotoxic at various stages of growth. The restricted-entry interval is 4 hours for insecticidal soap.

Ampelomyces quisqualis 0 day PHI. *Ampelomyces quisqualis* (AQ10) is a biofungicide which is a selective fungal hyperparasite. Use rates are from 0.5 - 1.0 oz/acre. This product works well early in the season but is less effective in inland growing regions. It is also incompatible with other fungicides so its use is usually limited to the early season in coastal growing regions. The restricted-entry interval is 4 hours for *Ampelomyces quisqualis*.

Potassium Bicarbonate. 0 day PHI. Potassium bicarbonate (KALIGREEN) is a new product available to the industry. Though less effective than traditional controls of powdery mildew, this product works well in rotation with these products and is a good reduced-risk addition to an IPM program. It should be applied in cooler climates as applications during high temperatures may cause bronzing of fruit. The product is applied at a rate of 2.4 lb ai per acre. There is no data yet on the extent to which this new active ingredient is being used on strawberries in California. The restricted-entry interval for potassium bicarbonate is 4 hours.

Narrow Range Oil. Narrow range oils (such as STYLET OIL) may be alternated prebloom with other fungicides such as sterol inhibitors. Good coverage is essential for the product to be effective against powdery mildew.

PHYTOPHTHORA CROWN ROT & ROOT ROT

Phytophthora cactorum
Phytophthora citricola
Phytophthora parasitica
Phytophthora megasperma

Damage. *Phytophthora* is a genus of soil-borne fungi. Stunting is common. Initially, the youngest leaves on the strawberry plant begin to wilt and also may turn bluish green in color. Plant collapse also occurs rapidly or slowly, depending on the *Phytophthora* species involved. When infected plants are cut open, a brown discoloration can be seen throughout the crown tissue. *Phytophthora* species also attack root tissue, causing a brown to black root rot.

Description of Infection. Motile spores (zoospores) are released into the soil and swim to plant tissue when the soil becomes saturated with water for prolonged time periods. When the soil

drains and dries, zoospores either encyst or die. Mycelium in infected tissues make resistant structures that overwinter and survive harsh conditions.

CONTROL

Cultural

Low Moisture. Cultural control of the fungus includes locating strawberry fields on well drained soil, using raised beds to provide optimum drainage, and using less susceptible cultivars. Use of drip irrigation and managing irrigation schedules to minimize soil saturation near plant crowns are key methods reducing losses from this pathogen. Planting in low lying areas that regularly receive excess water and are poorly drained is avoided.

Resistance/Prevention. In so far as possible, growers also use clean plant stock when available and cultivars suitable for local conditions that have disease tolerance.

Varieties. Though some varieties are less susceptible to Phytophthora, this is rarely an important basis for varietal selection by the growers. Furthermore, resistance in main varieties is incomplete to phytophthora.

Chemical

Methyl Bromide/Chloropicrin. Fumigating the soil with methyl bromide/chloropicrin is a key component of crown rot control, although the use of fungicide soil drenches or sprays is also of use. Methyl Bromide with chloropicrin is applied as a preplant application to fields at a combined rate of 300 to 400 lbs/acre to control Phytophthora crown rot. It is typically applied to essentially all of the fruit production acreage and to all nursery acreage in California. Methyl bromide applications are highly controlled and restricted and the active ingredient will no longer be available in 2006. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Mefenoxan. 0 Day PHI. Mefenoxam (RIDOMYL GOLD) has recently become available for fungicidal use in strawberries. The ingredient is a reduced-risk substitute for the chemically related metalaxyl (RIDOMYL). Mefenoxam is applied at label rates. There is no information available yet on the extent of mefenoxam's use since it is a recently registered active ingredient in California. The restricted-entry interval is for mefenoxam is 48 hours.

Fosetyl-Aluminum. 0 day PHI. Fosetyl-al (ALIETTE) is applied at label rates to affected areas to slow the progress of the disease. Fosetyl-al is applied to about 1% of

Insecticidal Soap. 0 day PHI. Insecticidal soap is applied at rates of 5.5 lb ai/acre. It is not used on new transplants, un-rooted cuttings, or water-stressed plants and should not be applied when leaf temperature exceeds 90°F. These soaps can be phytotoxic at various stages of growth. The restricted-entry interval is 4 hours for insecticidal soap.

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Narrow Range Oil. Narrow range oils (such as STYLET OIL) may be alternated prebloom with other fungicides such as sterol inhibitors. Good coverage is essential for the product to be effective against powdery mildew.

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CONTROL

Cultural

Low Moisture. Cultural control of the fungus includes locating strawberry fields on well drained soil, using raised beds to provide optimum drainage, and using less susceptible cultivars. Use of drip irrigation and managing irrigation schedules to minimize soil saturation near plant crowns are key methods reducing losses from this pathogen. Planting in low lying areas that regularly receive excess water and are poorly drained is avoided.

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Varieties. Though some varieties are less susceptible to Phytophthora, this is rarely an important basis for varietal selection by the growers. Furthermore, resistance in main varieties is incomplete to phytophthora.

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Fosetyl-Aluminum. 0 day PHI. Fosetyl-al (ALIETTE) is applied at label rates to affected areas to slow the progress of the disease. Fosetyl-al is applied to about 1% of

strawberry acreage at an average rate of 2.3 lbs ai/acre. The restricted-entry interval is 12 hours for fosetyl-al.

COMMON LEAF SPOT

Ramularia tulasneii

Damage. Common leaf spot is the most important of the strawberry leaf spot diseases in California. The disease is not as important as it has been in previous years, particularly in south coast regions. However, the disease can decimate the productivity of fields if unchecked. The pathogen is introduced into fruit production fields as small, black sclerotia on infected nursery material. Germination of sclerotia is initiated by fall and winter rains or sprinkler irrigation. Spores are dispersed by wind-driven rain. Common leaf spot can be a problem in all nursery and fruit production areas, but is usually less prevalent in the drier interior valleys and southern growing regions.

Description of Infection. Small, deep purple spots initially appear on the upper surface of leaves, with the center portion of the lesion turning brown then gray to white depending on the age of the leaf and environmental conditions. Numerous spots may coalesce to kill the leaf. On petioles, stolons, calyxes, and fruit trusses, elongated sunken lesions may form and interfere with water transport in the plant, weaken the structure, or allow invasion by secondary organisms.

CONTROLS

Cultural

Drip Irrigation. Overhead irrigation is avoided. The use of drip irrigation can limit the onset of the disease.

Leaf Removal. Though not always practical, removal of infected leaves can limit spread of the disease.

Clean Stock. Attempts are made to insure that planting stock is clean, limiting introduction of the disease into a new field.

Chemical

Protective fungicides are effective if used at the appropriate time. Applications are made in anticipation of warm, damp weather.

Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant application to fields at a rate of 300 to 400 lbs/acre to kill overwintering sclerotia. It is typically applied to essentially all fruit production acreage and all nursery acreage in the state. Methyl bromide/chloropicrin is effective against sclerotia in the soil. These applications are highly restricted and methyl bromide is being phased out by 2006. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Chlorothalonil. 0 day PHI. Chlorothalonil (BRAVO) is an aromatic hydrocarbon derivative applied at rates of about 1 lb ai/acre to nonbearing stock in nurseries only. It is applied to about 3% of overall strawberry acreage (which is a significant portion of the state's nursery acreage). This material is available as a special local needs registration and may only be applied by permit from a county agricultural commissioner. Chlorothalonil should not be used with or closely following spray oils. There is no restricted reentry period.

Captan. 0 day PHI. Captan is a N-trihalomethylthio applied at 2 lb ai/acre to over 90% of treated acres of strawberry fields with an average of 3 applications per year (though these applications are typically targeted towards the control of other diseases. It is not applied in combination with or immediately following application of spray oils. The restricted entry interval is 1 day.

Benomyl. 1 day PHI. Benomyl (BENLATE) is a carbamate applied at rates of 0.5 lb ai/acre onto about 40% of the strawberry acreage though typically not targeted toward common leaf spot. Rarely used alone, benomyl is typically used in combination with captan or other fungicides. A total of 5 lbs ai per acre per year is the maximum rate allowed. The restricted reentry period is 4 hours.

Copper Hydroxide. 1 day PHI. Copper hydroxide provides some control of common leaf spot at label rates. It is applied to about 9% of strawberry acreage. The restricted reentry interval is 48 hours.

Myclobutanil. 3 day PHI. Myclobutanil (RALLY) is an azole fungicide applied at a rate of 0.1 lb ai/acre. It is applied to approximately 65% of strawberry acres though primarily targeted towards the control of other diseases. The average number of applications per year is 2 though up to 6 applications per year are allowed. Though effective against common leaf spot, it must be applied in conjunction with its targeted use against powdery mildew. The restricted entry interval for myclobutanil is 48 hours.

Potassium Bicarbonate. 0 day PHI. Potassium bicarbonate (KALIGREEN) is a new product available to the industry. Though less effective than traditional chemical treatments against common leaf spot, this product works well in rotation with these products and is a good reduced-risk addition to an IPM program. The product is applied

at a rate of 2.4 lb ai per acre. It should be applied in cooler climates as applications during higher temperatures may cause bronzing of fruit. There is no data yet on the extent to which this new active ingredient is being used on strawberries in California. The restricted reentry period is 4 hours.

ANTHRACNOSE

Colletotrichum acutatum

Damage. Anthracnose is a sporadic disease that is most common in wet, El Nino years , especially in Southern California. Flowers, ripe and unripe fruit can be affected. Warm or cool, wet conditions favor the development of fruit and stem rot. Anthracnose can also cause root rot and crown rot. The worst problems from this disease come from nursery stock.

Description of Disease. On fruit, light tan to light brown water-soaked lesions develop and turn into sunken black lesions. Dark elongated fusiform lesions appear on petioles and runners, and often girdle the stem. Fungus overwinters in plant debris or alternate weed hosts.

CONTROLS

Cultural

Planting Stock. Anthracnose is most common on varieties that fruit in the nursery. Contamination may occur in fruit production fields as a result of nursery infections or contamination of planting material. Growers use certified “clean” pathogen-free planting stock in fruit production fields and use drip irrigation to prevent the spread of disease, avoiding overhead sprinkler irrigation.

Removal of Soil. Water (hot water, if possible) can be used to remove soil from planting stock prior to transfer and to reduce potential for transfer of disease.

Biological

There are no specific biological control methods for anthracnose.

Chemical

Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a pre-plant fumigation to fields at a combined rate of 300 to 400 lbs/acre. It is typically applied to essentially all of California’s production and nursery acreage. Methyl bromide use is

highly restricted and will be phased out by 2006, with a 70% reduction by 2003. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Post-Plant.

Day neutral varieties are treated in nurseries when plants begin to fruit. Treatments are made in the field before an expected rain.

Myclobutanil. 3 day PHI. Myclobutanil (RALLY) is an azole fungicide applied at an average rate of 0.1 lb ai/acre. It is applied to approximately 65% of strawberry acres though primarily targeted towards the control of diseases other than anthracnose. Myclobutanil can be effective against anthracnose but must be used in conjunction with treatments targeting powdery mildew. The average number of applications per year is 2 though up to 6 applications per year are allowed. The restricted entry interval for myclobutanil is 48 hours.

Benomyl and Captan. 1 day PHI. A combination of benomyl and captan is the typical treatment for anthracnose. It is not applied in combination with or immediately following application of spray oils. The restricted entry interval is 1 day.

Captan. 0 day PHI. Captan is a N-trihalomethylthio fungicide applied at an average rate of 2 lb ai per acre. Captan is applied to over 90% of the strawberry acreage to treat several fungal diseases. It is not applied in combination with or immediately following application of spray oils. The restricted entry interval is 1 day for captan.

The following active ingredients are not currently registered for strawberries but are needed tools as soon as possible. An expedited registration is encouraged by the industry.

Azoxystrobin. Azoxystrobin (QUADRI) is a new active ingredient that is needed for strawberries in California for disease control and to manage fungicide resistance.

Cyprodinil With Fludioxonil. The combination of cyprodinil and fludioxonil (SWITCH) is available as a Section 18 for Strawberries in southeastern United States. This reduced risk combination is needed now for disease control and to manage fungicide resistance.

SECONDARY DISEASES

It is important to note that all discussion related to pest control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

LEATHER ROT

Phytophthora cactorum

Damage. Leather rot of strawberry fruit is not common on most annual plantings of strawberries in California. Plantings held for 2 or 3 years, however, can be infected by the leather rot pathogen. Infected fruit is bitter and has tough areas where infections appear.

Description of Infection. All stages of fruit are susceptible to leather rot. The fruit appears dull and lifeless, ranging in color from light purple to ripe red. The external infected area becomes tough, while the internal tissue is somewhat softer with vascular tissue turning dark brown. The fruit tastes bitter.

CONTROLS

There are very few options that are effective in control of leather rot. Though this disease is currently of little concern, the loss of methyl bromide may have a significant impact on the onset of this disease.

Cultural

Sanitation. Diseased fruit is removed from the field and plastic mulches are used to control the disease.

Drip Irrigation. Growers use drip irrigation, and avoid overhead irrigation.

Crop Rotation. Disease establishment can be limited by replanting annually or by rotating the fields through other crops.

Biological

There are no biological control methods that target leather rot.

Chemical

This disease is largely controlled through the widespread use of methyl bromide. The removal of this chemical from the marketplace is likely to cause an increase in the occurrence and severity of leather rot.

Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant fumigation to fields at a combined rate of 300 to 400 lbs/acre. It is typically applied to essentially all of the strawberry acreage in California to provide control of pathogenic fungi, weeds, and nematodes. Methyl bromide is a highly restricted use material and will no longer be available in 2006. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

The following products are potentially available for the control of leather rot but are not very effective and are rarely, if ever, used for this purpose.

Fosetyl-Aluminum. 0 day PHI. Fosetyl-aluminum (ALIETTE) is applied at an average rate of 2.3 lb ai per acre to only 1% of strawberry acreage but rarely for control of leather rot. The restricted-entry interval for fosetyl-al is 12 hours.

Captan. 0 day PHI. Captan is a N-trihalomethylthio fungicide that provides good control in the coastal areas and is applied at an average of about 2 lb ai/acre to greater than 90% of strawberry acreage though rarely for the control of leather rot. It is not applied in combination with or immediately following application of spray oils. The restricted-entry interval is 1 day for captan.

Thiram. 3 days PHI. Thiram is a dithiocarbamate applied at about 2 lb ai/acre to 60% of treated acres of strawberry fields though rarely to control leather rot. It is not applied in combination with or immediately following application of spray oils. The average number of thiram applications per season is 2. The restricted-entry interval is 1 day for thiram.

Mefenoxam. 0 Day PHI. Mefenoxam (RIDOMYL GOLD) has recently become available for fungicidal use in strawberries. The ingredient is a reduced-risk substitute for the chemically related metalaxyl (RIDOMYL). Mefenoxam is applied at label rates. There is no information available yet on the extent of mefenoxam's use since it is a recently registered active ingredient in California. The restricted reentry period is for mefenoxam is 48 hours.

MUCOR FRUIT ROT

Mucor spp.

Damage. Mucor Fruit Rot is not a commonly seen disease in California strawberries though outbreaks do occur, often in conjunction with outbreaks of Rhizopus Fruit Rot. The disease invades the fruit through the slightest wound. Under conditions of high humidity, the berry becomes covered with a coat of tough, wiry mycelium and black spore-bearing structures. High temperatures trigger onset of the disease.

Description of Infection. Like the fungus that causes Rhizopus fruit rot, Mucor fruit rot invades the fruit through wounds. The fungus secretes an enzyme that rapidly results in a leaky fruit rot. The fungus produces millions of airborne spores that are favored by warm, moist conditions. Because the fungus lives on dead and decaying organic matter, field sanitation is important.

CONTROLS

Cultural

Post-Harvest Cooling. Immediate post-harvest cooling of the berries can reduce the severity and impact of the disease though this practice does not work on all varieties. Unlike *Rhizopus*, some *Mucor* species such as *M. mucedo* and *M. piriformis* are not inhibited by cold temperatures.

Sanitation. Fields are kept clean of all plant debris. Growers remove all ripe fruit from the fields. After rains, all ripe and near ripe fruit is removed from fields and destroyed. Good sanitation is practiced during harvest, packing, transport, and storage.

Chemical.

Though protective, broad-spectrum fungicides are available for use to control Mucor fruit rot, they are rarely used to target this disease. Treatments are made before the advent of cool to warm, moist weather after fruit set has begun.

Thiram. 3 days PHI. Thiram is a dithiocarbamate applied at about 2 lb ai/acre to 60% of treated acres of strawberry fields though rarely to control mucor fruit rot. It is not applied in combination with or immediately following application of spray oils. The average number of thiram applications per season is 2. The restricted-entry interval is 1 day for thiram.

Captan. 0 day PHI. Captan is a N-trihalomethylthio fungicide applied at 2 lb/acre to approximately 90% of strawberry acres though rarely for the control of Mucor fruit rot. It is not applied in combination with or immediately following application of spray oils. Captan is applied anywhere from 1 to 12 times per season, with 3 applications per season being the statewide average. The restricted entry interval is 1 day for captan.

ANGULAR LEAF SPOT

Xanthomonas fragariae

Damage. The adverse impacts of angular leaf spot are increasing. The disease is a severe problem in all nursery locations and is becoming more of a problem in fruit production regions such as the central and south coast. The disease is favored by cool, moist days with cold nights near freezing. Infection first appears as minute, water-soaked spots on the lower surface of leaves. The lesions enlarge to form translucent, angular spots that are delineated by small veins and often exude a viscous ooze, which appears as a whitish and scaly film after drying. As the disease progresses, lesions coalesce and reddish brown spots, which later become necrotic, appear on the upper surface of the leaves. A chlorotic halo usually surrounds the infected area.

Description of Disease. This bacterium is not free living in soil. It can, however, overwinter in soil on previously infected plant material. Transmission is by splashing water. It is host specific and highly resistant to degradation. The disease can persist in the soil for long periods of time. It is killed by methyl bromide/chloropicrin mixture used as a preplant fumigant, so it is very likely that most initial infections in fields that have been fumigated originate from contaminated plants. Lesions on the leaf surface serve as a source for secondary inoculum and cells are dispersed by splashing rain or overhead irrigation. Although uncommon in California, *Xanthomonas fragariae* can cause vascular collapse and can be confused with phytophthora crown rot and root rot, *Colletotrichum* crown rot and Verticillium wilt. This symptom initially appears as a water-soaked area at the base of newly emerged leaves. Shortly after, the whole plant suddenly dies, much like plants infected with crown rot.

CONTROLS

Cultural

Sanitation. Growers use certified clean planting stock though the certification system has become less reliable in recent years.

Drip Irrigation. Growers avoid overhead irrigation whenever possible. Drip irrigation and other limited water programs can be effective in reducing spread of the disease.

Biological

There are no specific biological control methods for angular leaf spot.

Chemical

Chemical controls are typically ineffective against this pathogen.

Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant fumigation to fields at a combined rate of 300 to 400 lbs/acre. It is typically applied to essentially all of California's production and nursery acreage. Methyl bromide use is highly restricted and will be phased out by 2006, with a 70% reduction by 2004. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Fixed Copper. 1 day PHI. Fixed Copper is applied at label rates to approximately 10% of strawberry acreage. Copper can be phytotoxic to plants with repeat applications. The restricted-entry interval for fixed copper is 24 hours.

RED STELE

Phytophthora fragariae

Damage. Red Stele is not as important in California as it is in Eastern growing regions due to soil fumigation, raised beds, drip irrigation and lower rainfall. However, it is expected to increase as methyl bromide is phased out. The symptoms of this disease include severe stunting followed by death of plants. Optimum conditions for disease development occur when the soil is saturated. Zoospores (motile spores) swim to the roots and infect them. Well-drained soil and warmer soil temperatures, such as often occurs in California's growing regions, reduces and delays disease development. As a result, Red Stele represents only about 5% of the economic impact of phytophthora-based diseases in California. The incidence of this disease is expected to increase with the phase out of methyl bromide and the increased use of opaque mulches, which reduces soil temperature, for weed control.

Description of Infection. Symptoms first appear in plants located in low, poorly drained parts of the field. Plants become stunted as older leaves die and are replaced by smaller, younger leaves with short petioles. Young lateral roots are often completely rotted. New crown roots die from their tips back, producing a symptom called rattail. Splitting the root reveals the red stele from which the disease gets its name.

CONTROLS

Cultural

Moisture Limitation. Growers plant on raised bed, use carefully managed drip irrigation, good soil drainage, and keep soil pH up to at least 7.

Biological

There are no specific biological control agents against Red Stele.

Chemical

Methyl Bromide/Chloropicrin. Methyl Bromide with chloropicrin are applied as a preplant fumigation to fields at a combined rate of 300 to 400 lbs/acre to control red stele and many other soil-borne pests. This combination is currently applied to essentially all the production and nursery acreage in California. It is the only know control of red stele. Methyl bromide is being phased out and will no longer be available in 2006, with a 70% reduction by 2004. As a result, red stele may become a more economically important pest in future years. The restricted entry interval for methyl bromide/chloropicrin is 48 hours.

Mefenoxan. 0 Day PHI. Mefenoxam (RIDOMYL GOLD) has recently become available for fungicidal use in strawberries. The ingredient is a reduced-risk substitute for the chemically related metalaxyl (RIDOMYL). Mefenoxam is applied at label rates. There is no information available yet on the extent of mefenoxam's use since it is a recently registered active ingredient in California. The restricted-entry interval is for mefenoxam is 48 hours.

Fosetyl-Aluminum. 0 day PHI. Fosetyl-al (ALIETTE) is applied at label rates to affected areas to slow the progress of the disease. Fosetyl-al is applied to about 1% of strawberry acreage at an average rate of 2.3 lbs ai/acre. The restricted-entry interval is 12 hours for fosetyl-al.

WEEDS

Overview. The longer growing season of California strawberries results in a greater challenge to weed control. Effective weed management in strawberries requires a combination of cultural practices, preplant soil fumigation, and additional herbicide applications when necessary. Proper preplant field preparation and bed preparation are essential for a good weed control program. For weed and pathogen control, fumigation with a combination of methyl bromide and chloropicrin, or to a lesser extent metam sodium, in conjunction with plastic mulches, is a major method of weed control in California strawberries. A few growers in the warm Central Valley use soil solarization in place of preplant fumigation. For weeds that escape preplant controls, hand-weeding and/or selective herbicides are used. In some cases, organic mulches have been used instead of plastic ones.

Strawberries are highly susceptible to weed competition immediately after planting when the plants are small and frequent sprinkling provides ideal conditions for weed germination. Most weeds that invade strawberries are annuals. During stand establishment, **little mallow bur**, **clover** and **sweet clover**, and **filaree** are common weeds because their seeds survive fumigation.

Once strawberries are in the bearing stage of growth, windblown weed seeds including **sowthistle**, **common groundsel**, and **grasses** may become problems. In certain sites, perennial weeds such as **field bindweed**, **spurge**, and **bermudagrass** may require control, especially in fields where the crop is carried over into a second year of production. In areas where strawberries are carried over for 2 years, weed management during the second winter consists of a combination of preemergence herbicides, mulches, and/or hand-weeding.

Growers select sites with good drainage in areas with good quality water. Fields are surveyed for perennial weeds. The broad-spectrum control of methyl bromide allows for the use of land that may have a weedy history, but less weedy sites are preferred. Certain weeds (such as **hairy nightshade**) host soil-borne diseases (such as Verticillium wilt). Treatment of these weeds, therefore, can result in a lower incidence of soil-borne diseases. During the early stages of plant establishment, growers must check frequently for weeds (at least once every 3 weeks during the first 3 to 4 months after planting). Weeding crews are sent through fields, as needed, to remove weeds.

The loss of methyl bromide in 2006, with incremental reductions of 25% in 1999, 50% in 2001, and 70% in 2003, will have a dramatic impact on the effectiveness of weed control in California's strawberries. Productivity losses are anticipated due to increasing competition for soil and sun and increased abundance of hosts for insect pests and diseases. Alternative fumigants, such as 1,3-D plus chloropicrin mixture and chloropicrin alone, are less active on

weeds than methyl bromide. Therefore, weeding costs are likely to increase during and after the methyl bromide phase out.

CONTROLS

It is important to note that all discussion related to weed control are based on pest management strategies utilizing certified pest/disease free nursery stock growing in soil treated with methyl bromide/chloropicrin.

Cultural

Weeds can be controlled culturally through the use of mechanical methods or with organic and synthetic mulches.

Hand Weeding. During the early stages of plant establishment, mechanical removal, mostly by hand, is the most practical means for control. Timely removal of weeds is essential to minimize competition.

Mulches, Organic. If leaves are pruned during the winter, organic mulches are sometimes applied at this time to suppress weed infestation. To control weeds effectively, at least 2 inches of mulch is necessary and must be maintained to keep weeds from growing through the mulch. Organic mulches may increase problems with snails, slugs, earwigs, and possibly other insects. Examples of organic mulches include wood shavings, chopped straw, and rice hulls.

Mulches, Synthetic Opaque. Synthetic mulches are usually some type of opaque plastic. These may be brown, black, or white, but they must restrict light from penetrating the film to be effective. Some of the darker color mulches can result in yield losses, particularly in the south coast growing regions. For example, dark mulches such as brown, black and green mulches can reduce yields by 10% to 15% in the south coast regions. Opaque mulches can be an effective method of weed control. Opaque mulches are secured to the soil before transplanting. Strawberry plants are planted into the soil after burning a hole into the plastic at the desired spacing. Weed growth is greatly reduced with opaque mulches, but weeds still grow in the hole where the strawberry plant is and need to be removed by hand. Opaque mulches do not heat the soil sufficiently for early fruit production and high yields.

Solarization with Mulches, Synthetic Clear. In summer, clear plastic is applied to preshaped beds several weeks before planting to solarize the soil and reduce the number of weed seeds and possibly disease organisms. On the central coast, this practice requires at least 12 to 15 weeks in order to obtain pest management benefits; consequently,

solarization may not be practical substitute for fumigation on the coast. The effectiveness of solarization is much better in areas of the state where temperatures are consistently hot in summer, such as the San Joaquin Valley. In South Coast winter plantings, clear plastic mulches are commonly used to promote early harvest. Clear plastic serves as a greenhouse to encourage early strawberry growth. Unfortunately, viable weed seeds in the strawberry beds will also germinate in the warm soil and grow under the plastic. Therefore, it is critical that an effective fumigant be used that eliminates all viable weed seeds in the upper 2 inches of the planting bed. Once the mulches are in place, controlling weeds below them is difficult and time consuming.

Mechanical Weeding. Weed seed reservoirs can be reduced by off-season growth and mechanical removal, however, this practice is not practical in many of the growing regions within the state and is rarely, if ever practiced. Following bed formation, growers can sprinkler irrigate to germinate weeds, thus reducing the weed seed reservoir in the soil. Irrigation is followed with timely removal of weed growth with minimal soil disturbance. Cultivation equipment is used for furrows, but the sides and tops of beds must still be hand-weeded. Hand weeding is the most practical means of weed control.

Because most California strawberries are planted in the fall-winter period, this practice is accomplished in mid-to-late summer. This works well in coastal climates where soil temperatures are usually cool enough for winter weeds to germinate year round. In the interior valleys with warmer climate, winter annuals may not germinate during this period and mechanical weeding is not effective.

Chemical

For effective weed seed control it is essential, regardless of fumigant, that the soil be pre-irrigated so that weed seeds are saturated with water before fumigation and that soil temperatures be above 55°F. The following fumigants are used for weed control.

Methyl Bromide/Chloropicrin. Methyl Bromide with Chloropicrin is applied as a preplant fumigation to fields at a rate of 300 to 400 lbs/acre to control weeds and other soil-borne pests. This combination is currently applied to essentially all of the production and nursery acreage in the state. Soil fumigation must be performed at least 14 days before planting. This time period may vary with soil temperatures and dosage rates. Methyl bromide is being phased out and will no longer be available in 2006, with a 70% reduction by 2004. Weed control will be much more difficult without this effective, extremely broad-spectrum herbicide. Herbicide substitutes are not available to substitute for the spectrum of methyl bromide efficacy. The restricted-entry interval for methyl bromide/chloropicrin is 48 hours.

Metam Sodium. Metam sodium is applied as a preplant fumigant to less than 1% of treated fields. Metam-sodium is an effective material provided it comes in contact with the target organism. Metam-sodium, a liquid at atmospheric conditions, is applied by several methods: it can be injected into sprinkler systems, shanked into soil and tarped, or water-run with drip tape systems. It is not a direct substitute for methyl bromide and different application techniques are needed to obtain optimum results. Problems with applications are due largely to nonuniformity of application as a result of poor land preparation and insufficient soil moisture, resulting in subsequent lack of control against the targeted pests. Metam sodium is a restricted use material and may only be applied by permit from a county agricultural commissioner. Soil fumigation must be performed at least 14 days before planting. This time period may vary with soil temperatures, dosage rates, tarping and color, and soil type. The restricted-entry interval for metam sodium is 48 hours.

With the current primary role of fumigants for weed control and the widespread use of plastic mulches, conventional herbicides are often used less frequently than in many other crops. Postemergence herbicides are ineffective due to the common use of plastic mulches that prevent the herbicide from contacting the weeds growing under the plastic mulch.

Napropamide. 0 day PHI. Napropamide (DEVINOL) is a pre-emergent herbicide applied at a rate of 4 lbs ai per acre to approximately 5% of strawberry acreage. It may be applied at transplanting or during the early stage of strawberry development. It is applied to the soil and must be incorporated within 7 days of application with sufficient rainfall or sprinkler irrigation. Napropamide is effective on little mallow and filaree if applied before the weeds have emerged. If the application is delayed to establish plantings, emerged weeds must be removed before application. The use of napropamide can delay maturity and result in 10% to 20% yield reductions, although this is not typically seen in banded bed fumigation. The residual period is 4 to 10 months. The restricted entry interval is 12 hours.

Paraquat Dichloride. 21 day PHI. Paraquat dichloride (GRAMOXINE) is a post emergent herbicide used on 4% of the strawberry acreage at an average rate of about 0.6 lb ai per acre. Paraquat is often used to target weeds in furrow bottoms. The restricted-entry interval for paraquat dichloride is 48 hours.

Sethoxydim. 7 day PHI. Sethoxydim (POAST) is a post-emergent herbicide applied to much less than 1% of the strawberry acreage. Sethoxydim is effective only on grass weeds (except annual bluegrass). Annual bluegrass is the only major grass weed in strawberries on the Central Coast, therefore, sethoxydim is not widely used. The restricted-entry interval is 12 hours.

Chlorthal-Dimethyl (DCPA). 0 day PHI. Chlorthal-dimethyl (DACTHAL) is a preemergent herbicide that is applied to much less than 1% of the strawberry acreage. It may be applied at transplanting or during the early stage of strawberry development but not after bloom. DCPA is labeled for application both before or immediately following planting. This herbicide is no longer being manufactured and once existing supplies have been exhausted will no longer be available. The restricted-entry period is 24 hours.

Glyphosate. Glyphosate (ROUNDUP) is not registered for use in strawberry fields and would not be anticipated to be very effective since it is not compatible with the use of plastic mulches.

Oxyfluorfen. Oxyfluorfen (GOAL) is not practical for use on strawberries due to the long replant period required following application. Use would be limited to long fallow periods, a rare condition for fields which are typically in production most of the year.

VERTEBRATE PESTS

Overview. A number of vertebrate species may move into or live near strawberry fields that seek the fields for food. The potential for damage by vertebrates varies from field to field and region to region. Some fields are much more susceptible to damage. Migratory and resident birds can cause significant damage. Fields located near rangeland, wooded areas or other uncultivated areas are more likely to be invaded or re-invaded by certain vertebrates. Predators, diseases and food sources all may influence vertebrate populations. Predators such as coyotes, foxes, snakes, hawks and owls feed on rodent and rabbit species. Growers cannot, however, rely on predators to prevent rodents or rabbits from becoming agricultural pests.

BIRDS

HOUSE FINCH: *Carpodacus mexicanus*

ROBIN: *Turdus migratorius*

GOLDFINCHES: *Carduelis* spp.

CEDAR WAXWING: *Bombycilla cedrorum*

STARLING: *Sturnus vulgaris*

LONG-BILLED CURLEW: *Numenius americanus*

Damage. Several species can cause severe damage when they feed on ripening fruit in strawberry fields. Economic losses can be reduced by using frightening devices or preventing access during the harvest season by placing netting over the field.

House finches are the most troublesome bird pest in strawberries. They are residents in all strawberry growing regions and may feed in strawberry fields whenever ripe fruit is present.

Robins are present in strawberry fields throughout the year in some parts of southern California. In other regions, flocks of robins visit fields during migration, usually in late winter or early spring.

Goldfinches are small, bright yellow birds that typically feed on weed seeds, but in fall or in late winter large flocks may invade strawberry fields to feed on the seeds of the strawberry fruit.

Cedar waxwings are shiny, buff brown birds that have a characteristic crest and black mask over the eyes. They may cause serious damage to strawberry production in the central coast region.

Cedar waxwings move through fields in flocks of 20 to 50 birds during late winter and early spring migrations, destroying large quantities of ripening fruit.

Starlings, in large migratory flocks, may invade strawberry fields in late winter or early spring to feed on ripe strawberries. Resident starlings may feed in strawberry fields any time ripening fruit are present.

Long tailed curlews move through fields on the central coast, Santa Maria Valley and Oxnard Plain regions in early spring. They are large birds with a wingspan of about 2 feet, that have long legs and are characterized by a long bill that curves downward at the tip. Curlews feed in flocks of 10 to 20 and tend to return to the same areas each spring.

Monitoring. The best strategy for reducing bird damage depends on the species feeding on the crop. Growers identify the birds that are causing damage before choosing controls. Keeping records of bird problems and the time of year they occur, helps growers to plan control actions.

CONTROLS

Cultural

Visual Frightening Devices. Mylar stake flags are placed in fields to frighten away house finches. Visual frightening devices, such as mylar stake flags or large-eye balloons can also be used to reduce damage from robins and cedar waxwings. These visual repellents only reduce damage from goldfinches temporarily.

Noisemakers. Curlews are usually easily frightened. Noisemakers, such as shell crackers fired from shotguns are an effective control for this bird. For cedar waxwings and starlings, noisemakers can be effective if more than one kind is used. Because cedar waxwings and starlings quickly become accustomed to one type of noise, a combination of noisemakers (such as propane exploders, bird bombs, and shell crackers) is necessary to achieve control. Growers start using noisemakers as soon as the birds begin feeding in the field. Goldfinches are difficult to frighten with noisemakers. Noisemakers are not effective against house finches.

Traps. When the house finch population is high, trapping is an effective alternative, but may only be done with permit from the U.S. Fish and Wildlife Service. Starling are also trapped in modified Australian crow traps or converted cotton trailers placed near feeding or roosting sites.

Plastic Netting. Plastic netting placed over the crop is the most effective means of preventing damage from house finches, goldfinches, and cedar waxwings.

Shooting Prohibitions. Cedar waxwings are protected, therefore, they may not be shot. Shooting to scare or kill may be used for starlings, an unprotected species, since the shooting increases the effectiveness of other noise making devices when done occasionally.

CALIFORNIA GROUND SQUIRREL

Spermophilus beecheyi

Damage. Ground squirrels can be a serious problem in strawberry fields when populations have built up in adjacent areas and invade the fields to feed on fruit. Squirrels may also feed on leaves and stems and sometimes damage polyethylene irrigation hoses.

Monitoring. Growers monitor for ground squirrels by checking the perimeter of the field about once per month for animals or their burrows. If monitoring indicates that a squirrel population is moving in, they can be controlled with traps, fumigants, or toxic bait.

CONTROLS

Cultural

Traps. Trapping ground squirrels works well in small areas or for a small number of squirrels. Growers check the traps daily. Ground squirrels are classified as nongame mammals and can be eliminated at any time if injuring crops. Tree squirrels, however, are classified as game mammals by the California Fish and Game Code and a permit from the local game warden is required for control of the eastern gray squirrel and poisoning of this tree squirrel is illegal. The eastern fox squirrel may be eliminated in any manner if causing damage.

Chemical

Strychnine. Strychnine bait is applied at label rates to control ground squirrels. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed in traps and in burrows though this is an ineffective control method. Strychnine is rarely used by the strawberry industry since the baits are usually less attractive than the strawberry fruit.

Aluminum Phosphide. Aluminum phosphide is a phosphide fumigant that is used to control burrowing rodents. It works best in early spring when moist soil helps retain a high toxic gas level in the burrows. The burrows are checked after about three days.

Where squirrels have dug out, retreatment is necessary. It is rarely used on strawberry acreage.

Diphacinone. Diphacinone is an anti-coagulant rodenticide bait intended to control ground squirrels. It is applied at labeled rates to traps or in bait stations. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in the main tunnel. Diphacinone is a restricted use material that may only be applied with permit from a county agricultural commissioner. It is rarely used.

Zinc Phosphide. Zinc phosphide is a bait used to treat ground squirrels. It is rarely used in California.

MEADOW MICE

Microtus spp.

Damage. Meadow mice, which are also referred to as voles or field mice, inhabit roadsides, meadows, canal banks, fence-rows and many field crops. When mouse populations reach high levels in their native grassy habitats, they invade and occupy neighboring strawberry fields, feeding on ripening fruit.

Description. Full-grown meadow mice are larger than house mice but smaller than rats. Well-established populations can be recognized by the network of small runways through the grass or other cover and the openings of numerous shallow burrows. Meadow mice are active year round, day and night.

Monitoring. Growers monitor the fields by visually inspecting fields looking for active runways and burrows. Snap traps baited with a mixture of peanut butter and oats are also used to monitor the mouse populations.

CONTROLS

Cultural

Eliminate Habitats. Preventative measures are taken by growers to eliminate favorable mouse habitats adjacent to strawberry fields. Growers clear weeds along fence lines, field margins and irrigation and drainage ditches.

Eliminate Pest. Meadow mice are classified as non-game mammals and may be eliminated in any manner at any time if they are injuring crops.

Chemical

Diphacinone. Diphacinone is an anti-coagulant rodenticide bait applied at labeled rates. Baiting by hand is one of the most effective control mechanisms. Single dose baits can also be placed at intervals in an active runway, or burrow entrance. Diphacinone is rarely used in strawberries.

Zinc Phosphide. Zinc phosphide is a bait used to treat meadow mice at labeled rates. Zinc phosphide is not used in California strawberries.

MOLES

Scapanus spp.

Damage. Moles may invade strawberry plantings anytime during the year, destroying planting beds with their burrowing activity. Moles feed primarily on earthworms and soil arthropods, which are destroyed by soil fumigation; therefore, moles are more likely to invade second-year and unfumigated strawberry fields. Moles construct shallow feeding tunnels, which are apparent as linear ridges on the soil surface, and a series of deeper tunnels from which soil is pushed to the surface to form molehills. Molehills tend to be circular with a plug in the middle.

Description. Moles have cylindrical bodies with pointed snouts, dark, velvety fur, and spadelike front feet used for digging. They are active day and night and are rarely seen above ground.

CONTROL

Cultural

Traps. Moles are controlled by placing traps in or above tunnels. Traps placed in deeper tunnels are more effective because moles typically continue using deeper tunnels, whereas some surface tunnels are temporary.

MULE DEER

Odocoileus hemionus

Damage. In northern California, mule deer sometimes enter nursery fields destroying young strawberry plants by feeding on them and trampling them. They feed on plants and fruit, in fruit production fields located near good deer habitat. Deer are most likely to be a problem from late

spring to midsummer in low-elevation nurseries. Deer feed at night and early in the morning. Growers identify deer pests by footprints in the field and deer droppings.

CONTROLS

Cultural

Barriers. Growers erect deer-proof fences, 7 feet high. A six-foot mesh fence with several strands of smooth or barbed wire on top is most effective. Fences must be kept tight to the ground as some deer will crawl under the fencing to feed in the field. When only a few deer are involved, it may be economical and effective to have someone patrol the field with a spotlight to frighten the deer away.

Eliminate Pest. Depredation permits may be obtained from the California Department of Fish and Game to eliminate a few animals. This is a temporary solution, but may prevent further damage while a fence is being constructed.

RESEARCH

With the impending loss of methyl bromide as a pest management tool, the strawberry industry faces the challenge of developing a sound, multi-faceted, reduced-risk approach to integrated pest management that will provide viable biological controls, cultural practices and chemical tools for disease, insect and weed control. The continued economic success of the strawberry industry in California will be based, in part, on the industry's ability to develop a pest management program that balances sound cultural and biological control practices with chemical treatment.

Research and development into alternate pest management systems that can substitute for the current uses of methyl bromide is clearly the number one future challenge and focus of the industry's research efforts. Methyl bromide will no longer be available for use in 2006 and there are no comparable broad-spectrum tools available for control of soil-borne pests. Alternates to methyl bromide being assessed currently include the fumigants chloropicrin (alone), metam sodium, and 1,3-dichloropropene plus chloropicrin (TELONE C-35); however, substantial regulatory impediments exist for use of these methyl bromide alternatives. Chloropicrin alone is not permitted in certain counties within California. Metam sodium is under FQPA review by the United States Environmental Protection Agency and 1,3-dichloropropene is limited by township use and 300' buffer zones.

Narrow spectrum chemical tools are also being tested to substitute for parts of the wide array of pest control solutions that methyl bromide currently provides. For example, pesticides such as hexythiazox (SAVEY) may substitute for some of the miticidal properties of methyl bromide and herbicides may enhance the weed control activity of the methyl bromide alternatives. Examples of new soil-applied herbicides that may be used for this purpose are: carfentrazone-ethyl, flumioxazin, isoxaben and sulfentrazone. In areas where plastic mulches are not used, a post emergence herbicide, triflurosulfuron, may be a useful treatment to explore. The development of a glyphosate resistant strawberry will be of limited value in California due to the extensive use of plastic mulches that prevent glyphosate application to weeds growing below the plastic.

Enhanced use of cultural techniques such as mulching, solarization and plant breeding are also being considered by the strawberry industry. It is clear that, for California's strawberry industry, many different chemical and cultural tools will be needed in the near future to substitute for this single pest management ingredient.

Other areas of particular research needs are the development of control methods for Western Flower Thrips, mites, and lygus bugs. Diseases of increasing concern to the industry include Verticillium wilt, phytophthora crown rot and root rot, and red stele though significant increases in the resistance of botrytis fruit rot to existing fungicides has triggered increasing research into new pest management tools and expanded use of IPM by the industry.

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APPENDICES

- A. UC Pest Management Guidelines - Pest Diseases
- B. UC Pest Management Guidelines - Insects
- C. UC Pest Management Guidelines – Nematodes
- D. UC Pest Management Guidelines - Weed Management